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PHYSICAL FITNESS AS A MODERATOR OF COGNITIVE DEGRADATION DURING SLEEP DEPRIVATION

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

HENRY L. THOMPSON III, MAJ, USA
B.A., Methodist College, 1977
M.S., University of Georgia, 1979
Ph.D., University of Georgia, 1981

Fort Leavenworth, Kansas
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There has been considerable speculation in the military as to the ability of physical fitness to moderate cognitive degradation resulting from sleep deprivation during continuous combat operations. The purpose of this investigation was to test the hypothesis that the level of physical fitness would moderate cognitive degradation such that individuals in a high fitness group would show less cognitive degradation during sleep deprivation than individuals in a low fitness group. To test the hypothesis, 16 male ROTC students participated in a 48 hours field training exercise without sleep. Cognitive performance measures made at regular intervals throughout the exercise revealed significant cognitive performance degradation beginning at 24 hours. Degradation continued throughout the exercise. Performance decrements appeared to have recovered to pre-deprivation levels after 24 hours of rest. Analyses did not reveal a significant main effect of physical fitness level. Although there were several interesting findings, the physical fitness hypothesis was not supported.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

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CHAPTER I

INTRODUCTION

The modern battle field is changing rapidly. The long, drawn out wars like World War II, Korea, and Viet Nam may be a thing of the past. For example, during 5-10 June, 1967, Israel was involved in a very intense war with Egypt. Within a matter of hours the Israeli forces had gained air superiority by attacking over 16 Egyptian airfields as well as airfields in Syria, Jordan, and Iraq. By the 6th of June, the Israeli forces had penetrated deep into the Sinai Peninsula, captured the Gaza Strip, surrounded the Old City of Jerusalem, and advanced to the Jordanian West Bank Territory. Very intense and fierce fighting continued until 4:30 p.m. on the 10th of June. During those six days, literally thousands of lives were lost.

In 1973, the Egyptians launched a surprise attack on Israel. Adan (1979) described this war as "...a very intensive diversified campaign, fought by armies equipped with the best of modern weaponry...(that) experienced a wide range of combat situations: defense, offense, mobile warfare, infantry and armor ambushes, commando operations, night fighting, fighting in built-up areas and on mountainous terrain." During these three weeks of intense fighting, over three thousand tanks were destroyed. This is more than the total number of US tanks lost during the four

years of World War II.

A third example, although on a some what smaller scale, is the 1982 Faulkland Island dispute between Great Britain and Argentina. Once the British attack was underway, it was very intense, resulting in a decisive outcome within a matter of days.

These examples are presented to illustrate the "short war" trend of the second half of the Twentieth Century. They also point out, as participants of the wars have stated, that the fighting was characterized by intense operations requiring long hours of physically and mentally exhausting work with little or no sleep. These conditions had a deleterious effect on the decision making abilities of the leaders (Adan, 1979).

In 1954, The Soviet Union adopted sustained combat operations as the main principle for the development of their combat doctrine. This theme of high speed, sustained operations has remained consistent through today. The current Soviet doctrine (FM 30-102) emphasizes:

a. The use of massive artillery barrages to inflict maximum damage to the target prior to attacking with troops.

b. An attack designed to produce an overwhelming and sustained rate of advance by using two or more echelons in the attacking force. These forces rely on the use of a massive number of tanks and armored vehicles for rapid mobility.

c. Speed and shock more than fire and maneuver are

emphasized.

d. A rate of advance of 60-100 kilometers per day in a nuclear environment and 30-50 kilometers per day in a non-nuclear environment.

e. Moving as fast at night as during the day. To do this they have installed night vision devices on all of their tanks (except the PT-76), anti-tank guns, and armored fighting vehicles.

f. Overcoming natural obstacles, such as rivers, with a minimum reduction in the rate of advance.

g. Not relying on seizing or controlling terrain. The plan is to bypass areas of strong resistance and penetrate deep into their enemy's rear.

All of these tactics, combined with surprise, speed, and the technologically sophisticated equipment to accomplish it would make for another "short war."

Sustained Combat Operations

The short war of the future, as in the recent past, will be characterized by sustained (continuous) combat operations. Sustained operations are defined as those combat operations that are continuous for 24-120 hours without let up in the fighting. Operations of this type are made possible by:

a. The extensive mechanization of the military forces and increased emphasis on armor.

b. Recent advances in image intensifiers and other night vision devices.

c. The development of all-weather capable equipment such as the Air Force F-111A bomber, F-15, and F-16 fighters.

d. Advances in the field of electronic warfare.

e. The introduction of the computer to the battle field.

Sustained combat operations will result in a significant logistical problem: how to supply the forward units who will now require much more ammunition and fuel than in past wars. There will also be a personnel shortage that will affect not only the forward units, but the combat support and combat service support as well. Operations of all types (combat, logistical, and medical) will have to be conducted around the clock. Work shifts will have to be extended indefinitely in some cases. The increased work load will magnify the problems by the intensification of human factors in the system.

Human Factors

Human factors affecting performance during sustained combat operations can be dichotomized into exogenous and endogenous variables. Exogenous variables are independent of the individual and affect everyone involved in sustained operations. There are six primary exogenous demands (Hegge, 1981):

a. Muscle. These demands are related to the physical work to be performed and the muscle groups involved.

b. Perceptual-motor. These are related to the

requirements for eye-hand coordination.

c. Cognitive. These relate to decision making, vigilance, processing information, and communication.

d. Emotional. The relation of environmental factors that lead to increased physiological arousal.

e. Environmental. The relationship of the elements, e.g., heat, cold, altitude, etc., to the individual.

f. Temporal. Relates to when and how long the task must be performed.

Endogenous variables are different from exogenous in that they are specific to the individual. Consequently, there are wide variations in the effects of the demands of endogenous variables. Five primary endogenous variables have been identified (Hegge, 1981):

a. Physical fitness. There is an indirect relationship between level of aerobic (and anaerobic) capacity and resource utilization during physical work.

b. Age. The rate of resource utilization seems to vary directly with age and recovery work to vary inversely.

c. Job skills. The more skilled an individual is at performing a task, the longer he is able to sustain specified levels of task performance.

d. Health status. There are certain diseases (e.g., upper respiratory) that acutely affect performance under sustained operations.

e. Psychological fitness. During sustained combat operations, stress will increase dramatically. An

individual's ability to psychologically cope with this stress will significantly affect his resource utilization.

One product of the interaction of the above variables is fatigue. Fatigue has a significant debilitating effect on the individual's ability to perform even simple tasks. As advanced stages of fatigue set in, the individual will lose the ability to divide his attention between two tasks, and eventually, will not be able to sustain his attention to even one task.

The fatigue resulting from sustained combat operations will be primarily the result of two factors, physical exertion and sleep deprivation. To assist in understanding the effects of sleep deprivation, a short review of the sleep phenomenon will be presented.

Sleep

Sleep research has been conducted predominantly since the late 1920s. Since that time, there has been a steadily growing body of literature from the perspective of neurophysiology, biochemistry, pharmacology, endocrinology, physiology, and psychology (Webb, 1980).

In 1937, Loomis, Harvey, and Hobart demonstrated, by the use of brain waves, that the onset of sleep can be shown with remarkable clarity. Several years later, Azerinsky and Kleitman (1957) used brain wave measurements, electroencephalogram (EEG), to discover a cyclical pattern during sleep. Namely, that previously observed slow rolling eye movements suddenly became rapid after approximately 90

minutes of sleep. After a few minutes in this state, the rapid eye movement (REM) would cease and another 90 minute cycle would begin. The occurrence of REM led Azerinsky and Klietman to speculate that REM was associated with dreaming. Later, Dement and Kleitman (1957) demonstrated that most recallable dreams do take place during REM.

As sleep research continued, the use of the EEG resulted in the identification of well defined stages of sleep as well as sleep cycles. According to Coon (1982), the five stages of sleep are (see Figure 1):

a. Stage 0. Characterized by a state of wakefulness and beta waves.

b. Stage 1. The individual begins to lose consciousness. Breathing becomes irregular, heart rate slows, and the body relaxes. Sometimes, "noctural jerks" are observed. The EEG is characterized by small irregular waves with some alpha present.

c. Stage 2. During this stage, sleep deepens. The EEG begins to show bursts of "sleep spindles." d. Stage 3. In stage 3, the EEG takes on a slow and large pattern called "delta" waves. This indicates a deepening of sleep and a greater loss of consciousness.

e. Stage 4. Approximately one hour after the sleep cycle begins, a very deep sleep is reached. The EEG reflects almost pure delta waves. If an individual is awakened from this stage, he will display a state of confusion for a short period of time.

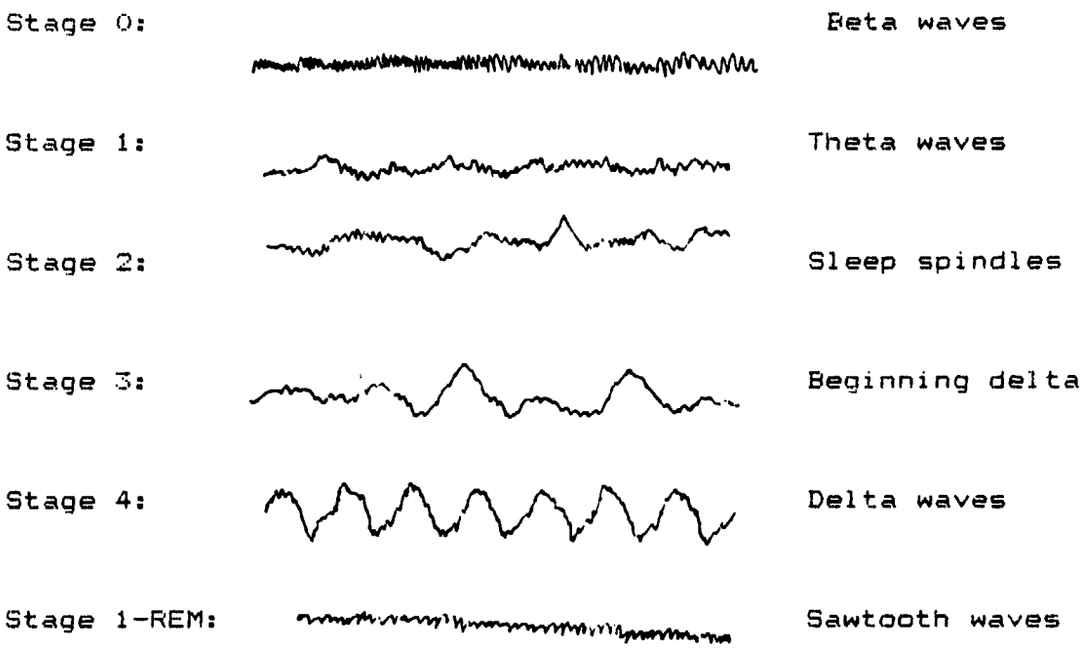

Figure 1

Brain Waves Associated with Sleep Stages

A sixth stage (Coon, 1982; Webb, 1973) has been labeled, "Stage 1-REM." During this stage, the EEG is similar to that of Stage 1, but there is also a state of REM and a paralysis of the voluntary muscular system. It is during this stage of sleep that the majority of dreaming takes place and is also the primary source of the dreams that the individual remembers when he awakens. Because of the almost "wake-like" state , and the accompanying muscle paralysis, Stage 1-REM has also been referred to as "paradoxical sleep."

Although the sleep stages are organized in a cyclical manner, they are not temporally linear. There is a variation in the amount of time spent in each stage during a particular cycle during the night. For example, the stages are entered sequentially from 1 to 4 during each cycle. However, the amount of time spent in Stage 4 decreases with each 90 minute cycle concomitantly with Stage 1-REM's increase. By the end of several cycles, very little, if any, time is being spent in Stage 4 and a large amount of time is in Stage 1-REM.

Sleep cycles are affected by numerous variables, such as age, diurnal cycles, stress, drugs, and sleep deprivation. The most profound changes in the sleep variable are seen across age. Webb (1980) describes several of these changes. For example, during the first few days of birth, the neonate sleeps an average of about 16 hours a day. (The range for this average is broad--10 to 22 hours.) By the age

of 4 weeks the sleep time has reduced to a mean of 15 hours, and to 13 1/2 hours by 26 weeks. The sleep time continues to decrease until the age of nine, where it has a mean of 8 hours. From this point through old age, there is little change in the mean duration of sleep. There is, however a significant change in the amount of time spent in the different stages as age increases. Generally, there is a trend for the amount of time spent in deep sleep (Stage 4) to decrease significantly beginning in the thirties.

Diurnal cycle. Another notable aspect of sleep that is affected by age is the distribution of sleep. As any parent can confirm, the neonate does not show a nocturnal sleep pattern. Neonates distribute their sleep throughout the 24 hour day, sleeping 30 or 40 minutes at a time. As the infant ages, he slowly develops a nocturnal sleep pattern. Webb (1980) attributes this to a maturational change rather than an environmental one.

A commonality shared by all, regardless of age, is the diurnal cycle. In 1938, Nathaniel Kleitman and Bruce Richardson lived for 32 days in Mammoth Cave, Kentucky. The cave provided them an unchanging environment of temperature and humidity. Although they had artificial lights, the light-dark cycle was not the same as an "ordinary" day. That is, they had their day extended to 28 hours: 19 for waking and 9 for sleep. Constant physiological measurements were made during the 32 days. The results of the experiment revealed that Kleitman's body stuck rigidly to a 24 hour

schedule (as revealed by temperature and sleep cycles). Richardson, however, easily adapted to the 28 hour day. Additional research indicates that Richardson is an atypical case. Humans, as well as plants and animals, operate on a cycle that approximates 24 hours (Brunning, 1973). This diurnal cycle tends to regulate physiologic functions. Behaviorally, we are strongly affected by the diurnal cycle. We eat, sleep, and exist based on the internal clock, even in a cave. Regardless of the light-dark cycle, we tend to maintain a 23-25 hour diurnal rhythm.

Physiologically, the diurnal cycle affects the body in several ways. The body temperature reaches its maximum between 1700-2300 hours; its minimum between 0300-0600 (Froberg, Karlsson, Levi, & Lidberg, 1975). Task performance peaks between 1200-2100 and reaches a low between 0300-0600 (Bugge, Opstad, & Magnus, 1979). Some other effects during the "night" portion of the normal day are:

a. A decrease in salivary and other glands of the mouth, nose, and throat. This eliminates the need to swallow (Oswald, 1962).

b. Lacrimal secretion decreases during drowsiness and sleep. This accounts for the burning sensation in the eyes when a person is getting sleepy (Oswald, 1962).

c. Gastric and biliary secretion decreases during the sleep cycle (Kleitman, 1939).

d. The heart rate slows and blood pressure decreases, especially systolic (Boas & Goldschmidt, 1932; Kleitman,

1939).

e. The pupils become restricted (Byrne, 1942).

f. The body metabolic rate slows down (Robin, Whaley, Crump & Travis, 1958).

g. There is a decrease in urinary secretion (Brunning, 1973).

These effects occur during the "night" time frame whether one is asleep or not. Obviously, they will not occur to the same extent when one is awake, but they do occur and affect human performance. It is important to note that the above occurrences are geared to the time zone in which a person currently resides. A trip to another time zone will result in some significant effects.

Jet-lag. The term "jet-lag" refers to the difficulty encountered when flying to a different time zone. By flying from east to west, one extends the hours in the "day." A person finds that he is are hungry in-between the new meal times and are sleepy before it is "time" for bed. The opposite is true of flying from west to east, i.e., the day is shortened. The jet-lag produced by the time zone crossings results in an initial decrement in performance because of the asynchrony of the diurnal cycle and the "day" cycle. This can have a serious affect on military units such as the Rapid Deployment Joint Task Force (RDJTF), that have a mission to deploy anywhere in the world within a matter of hours or days. They obviously will suffer from jet-lag (diurnal asynchrony).

Can diurnal asynchrony be countered? Klein, Bruner, Holtman, Rehme, Stolze, Steinhodd, and Wegmann (1970) found that the effects of diurnal asynchrony are greater when going from east to west than west to east. Pittendright (1965) reported that it may require less effort to adjust to a complete reversal of the day-night cycle than to changes of 6 hours. The human body can adjust to changes in the day-night cycle if given enough time. Most physiological processes will adjust within two weeks with body temperature being one of the slowest to change (Brunning, 1973).

Sleep deprivation. Sleep deprivation can create the same effects as "jet-lag." That is, extending wakefulness beyond the time when sleep would normally occur causes the body to function in asynchrony with the diurnal cycle. Reports of the effects of sleep deprivation range from severe performance decrements after a few hours to relatively little decrement after 240 hours (Goleman, 1982). However, the preponderance of the literature supports a direct relationship between performance decrements and hours of sleep deprivation.

Within a matter of a few hours after entering into sleep deprivation, the individual begins to feel "sleepy." As deprivation continues, sleepiness increases to a peak between 0200-0600 hours. During the late morning hours, the individual feels somewhat refreshed. As he enters into the afternoon, sleepiness begins to increase again. This cycle continues with the motivation to sleep becoming increasingly

stronger each cycle. The sleepiness cycle has been shown to be directly correlated with task performance (Haslam, Worsley, Dunn, Abraham, Few, Labuc, & Lawrence, 1977; Kleitman, 1931; Oswald, 1962; Webb, 1980). That is, sleep deprivation has a general deleterious affect on task performance and is particularly detrimental between the hours of 0200-0600.

Why is there a performance decrement during sleep deprivation? Sleep loss acts as a general depressant of the reticulating activating system resulting in a lowered cerebral vigilance (Kleitman, 1939; Oswald, 1962). (Vigilance has been defined by Mackworth (1957, p. 389) as "a state of readiness to detect and respond to certain specified small changes occurring at random time intervals in the environment.") This causes the individual to be less sensitive to exogenous stimuli. Thus, during a vigilance task, his performance will decrease. It is interesting to note that most errors made during vigilance tasks are those of omission rather than commission. There have been several theories posited to account for this:

a. Blocking theory (Bills, 1931). Proposes that fatigue creates a functional disturbance in the central nervous system (CNS) resulting in an interruption in the task orientation. This causes signals of short duration to be missed if they coincide with the CNS blocks.

b. Activation theory (Moruzzi & Magoun, 1949). This theory states that when the individual is exposed to

repeated stimuli in a similar sequence, the novelty of the stimuli will be attenuated and habituation will take place. With the loss of novelty, the stimuli will fail to activate the CNS and the signal will go undetected.

c. Self-stimulation theory (Bakan, 1957). When the individual is placed into an environment with a low level of exogenous stimulation, the reticulating activating system enters into a sleep-like state. For various reasons, the individual may have a desire for alertness and, thus, engage in self-stimulation. The effort required to maintain this self-stimulation may divert attention away from the task, and, therefore, result in missed signals.

d. Inhibition theory (Mackworth, 1957). This theory is related to reinforcement theory. It assumes that correctly responding to critical signals is reinforcing. But, that in vigilance tasks, the individual is not sure that he responded correctly (because of a lack of feedback). Therefore, he is not rewarded and an inhibition builds up that eventually results in response extinction.

All of the above have some merit, but the "micro-sleep" hypothesis may be more promising. This hypothesis proposes that the individual misses the signals because he lapses into momentary sleep (Williams, Lubin, & Goodnow ,1959). Physiological evidence has demonstrated that individuals in sleep deprivation vigilance tasks do emit momentary EEG patterns identical to those of sleep. (Some other general findings of sleep deprivation are summarized in Tables 1a

and 1b.)

Research on the effects of sleep deprivation on memory generally supports that short term memory (for recent events) is some what impaired (Oswald, 1962; Webb, 1980; 1982). Memory for more distal events is not affected (Siegel et al., 1982). Related to memory is the ability to learn new material. Seigel et al. (1982) report that after 24 hours of sleep deprivation, it takes significantly longer to learn new material than under normal sleep conditions. The difficulty in learning and memory, however, may be related to other factors such as visual perception.

Cappon and Banks (1960), Bliss, Clark, and West (1959), and Morris, Williams, and Lubin (1960) report perceptual illusions associated with sleep deprivation. These illusions, sometimes schizophrenic in nature, are very real to the individual. Oswald (1962) suggests that these illusions are the result of:

> The impairment in the direction of attention to information supplied by the sense organs and the failure of the normal ability to discriminate between fantasy and reality which takes place when cerebral vigilance falls.

Each of the effects mentioned above, including sleep deprivation, contributes to stress (Luby, Frohman, Grisell, Lenzo, & Gotlieb, 1969). Stress results in readily visible signs in the individual (Table 2).

Kopstein et al. (1982) have attempted to predict the

Table 1A

Effects of Prolonged Continuous Operations on Soldiers' Performance

DECREASED VIGILANCE. The soldier is less and less alert. For example, he fails to detect the appearence of targets.	SLOWED RESPONDING. The soldier is slow to respond to events. For example, there is a delay in translating a simple order into action.
REDUCED ATTENTION. The soldier is slow to notice changes of conditions or in the overall environment. For example, he is slow to notice hand signals or moving "bushes."	INCREASING OMMISSIONS. The soldier begins to skip tasks. For example, he fails to perform weapons checks.
SLOWED PERCEPTION. The soldier is slow in making sense out of things seen or heard, and especially of patterns. For example, he is slow to interpret the significance of changes in enemy fire patterns.	ENCODING/DECODING DIFFICULTIES. The soldier finds it difficult to transform data or to process information. For example, map/chart coordinates are encoded/decoded slowly, and mistakes are made.
INABILITY TO CONCENTRATE. The soldier cannot keep his mind on momentary activity. For example, he cannot follow complex directions or perform numerical calculations. He is confused.	FUZZY REASONING. The soldier's thinking or reasoning becomes slow and confused. For example, even simple tactical situations cannot be assessed.
FAULTY MEMORY. The soldier's short-term memory (for recent events) is faulty. For example, recent target data elements cannot be recalled or are recalled incorrectly.	COMMUNICATION DIFFICULTIES. Increasingly, the soldier has difficulty in deciding what needs to be said, how to say it, or what was said by someone else. For example, the soldier cannot formulate a coherent message and omits important information in issusing spot, status, or damage reports.
SLOWED COMPREHENSION. The soldier takes longer and longer to understand oral, written, or coded information. For example, he may take a long time to find a location on a map.	MOOD CHANGES. Significant changes in mood normally accompany performance degradation. These may include increased irritability, but will be mainly in the direction of depression and apathy.

NOTE: This Table was extracted from Kopstein et al. (1982, p. 8) with the permission of the US Army Research Institute for the Behavioral and Social Sciences.

Table 1B

Effects of Prolonged Continuous Operations on Soldiers' Performance

Novel stimuli retard performance decrement for up to 60 hours.	Repetitive, monotonous tasks show performance decrement as early as 24 hours.
Increasing task difficulty results in greater performance decrement.	Newly learned skills are more affected by sleep deprivation than well learned skills.
Micro-sleep occurs in increasing frequency as sleep deprivation continues.	The greater the amount of time the individual has to make a response, the less it is affected by sleep deprivation.
Communication tasks are adversely affected by sleep deprivation.	Variation of physical activity helps retard performance decrement.
The poorest task performance occurs between 0200-0600 hours.	There is an interaction of sleep deprivation and diurnal cycle.
There are wide individual differences in the effects of sleep deprivation.	Breaks in task performance help delay sleep deprivation effects.
Six hours of sleep is not sufficient for recovery from 48 hours of sleep deprivation.	Tasks of long duration show the largest performance decrement during sleep deprivation.

NOTE: These findings are paraphrased from Siegal, Pfeiffer, Kopstein, Wolf, & Ozkaptan (1980).

Table 2

Physical Signs of Serious Degradation

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* Vacant stare--eyes seem to be fixed and unfocused.

* Skin pallor--skin is pale.

* Postural instability--sways while standing up.

* Slowness of response--slow to respond to signals, directions, events.

* Lapses in attention--for moments the soldier is "not there," or seems asleep.

* Inability to grasp directions--has difficulty in comprehending orders, may have to repeat them to him several times.

* Difficulty with numbers--cannot keep numerical groups straight, cannot do simple arithmetic.

* Difficulties in expression-- has difficulty formulating verbal statements and messages.

* Unclear speech--speech may be slurred.

* Decision problems--has difficulty in reaching even the simplist kinds of decisions.

* Message garbling--incoherently relays messages, relay contains gaps and may be partly repetitive.

NOTE: This information was extracted directly from Kopstein et al. (1982, pp. 48-49) with the permission of the US Army Research Institute for the Behavioral and Social Sciences.

speed and extent of degradation resulting from sleep deprivation using computer simulations. They found a differential effect on duty positions resulting from the task performance requirements (Figures 2 & 3). Additionally, that the "leaders" of the organization suffer the greatest degradation. Thus, they are in the most need of sleep to counter degradation. Ironically, the leaders typically get less sleep than their subordinates.

The discussion above, although not exhaustive, has identified several effects of sleep deprivation on the individual. Are there any factors that can delay the deprivation effects? The current opinion in the military is that high levels of physical fitness can delay performance degradation during sleep deprivation.

Physical fitness. Throughout the course of history, the outcome of minor skirmishes, battles, and wars have been significantly influenced by the level of physical fitness of the participating warriors. Even in today's age of modern technology and weaponry, physical fitness cannot be over emphasized. The Secretary of the Army , John O. Marsh, Jr. (Note 1) recently stated:

> It is important that we emphasize physical fitness because...an individual serving in the Army (must have) the strength and endurance that enables him to carry out his combat mission. The history of great military units, particularly American military units, is a

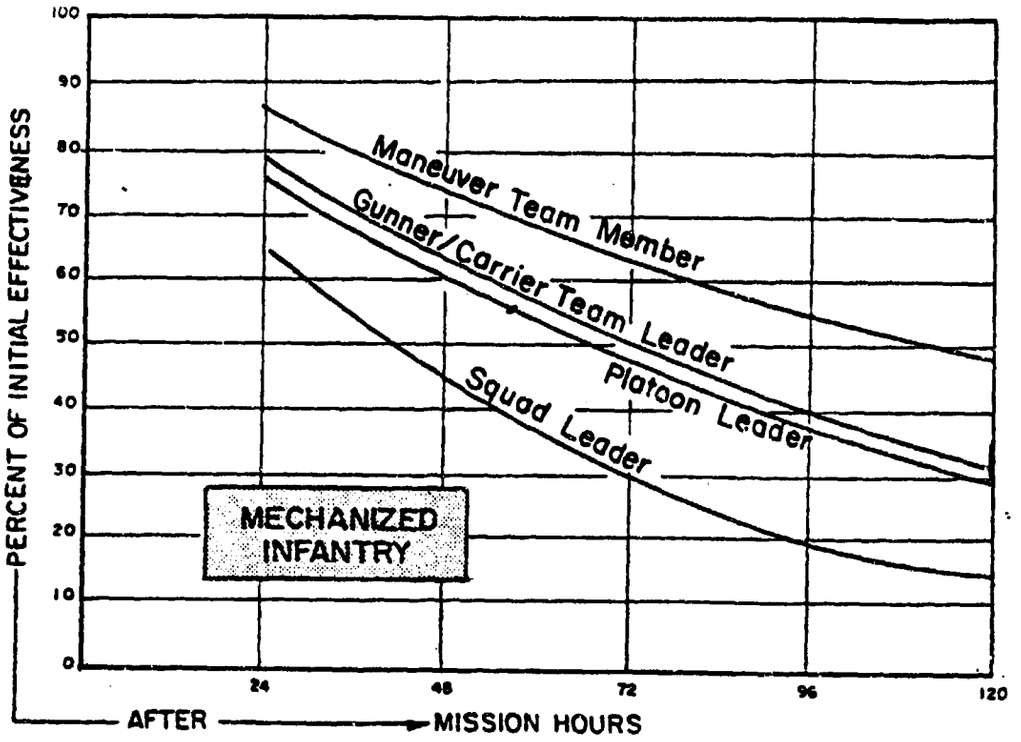

Figure 2

Projected Performance Degradation in Continuous Operations: Mechanized Infantry

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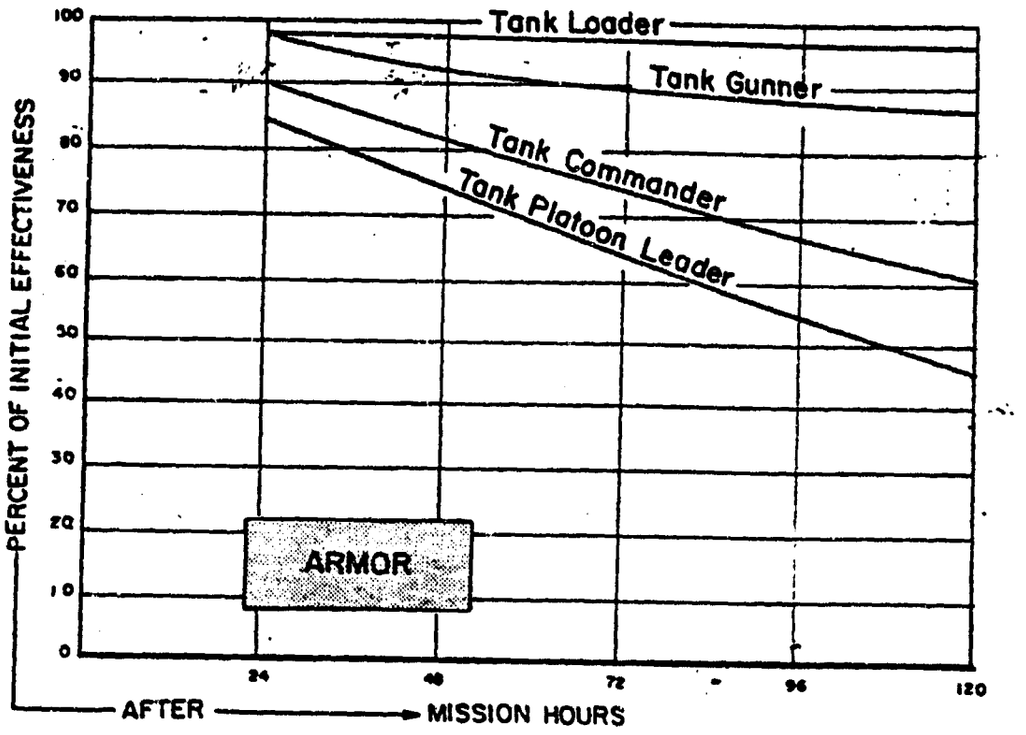

Figure 3

Projected Performance Degradation in Continuous Operations: Armor

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> history of units that could engage in long forced marches carrying equipment, yet take the field to engage successfully in combat.

LTG Julius W. Becton, TRADOC's Deputy Commanding General for Training and Army Inspector of Training (Note 2), speaking of physical fitness stated:

> If they (soldiers) are physically fit, we don't have to worry about them going 8, 10, 12, or maybe 24 hours in a crisis situation. If they are not physically fit, they are not going to be mentally alert. Physical fitness impacts on everything we do.

Thus, it a is common belief in the military that a high level of physical fitness is necessary in order to fight a protracted war, and, that physical fitness will delay performance decrements brought on by sleep deprivation.

Davey (1973) investigated the relationship between physical exertion and mental performance. He found an inverted "U" relationship. That is, as the amount of exercise increased, so did mental performance--to a point! Then, as exercise increased, performance decreased.

His findings suggest that mental performance is moderated by physiological arousal. This can be explained by the Yerkes-Dodson law of optimal arousal (Yerkes & Dodson, 1908). These results also suggest that periods of moderate physical exercise during sleep deprivation may temporarily reduce some of the mental performance decrement. But what

about the individual's level of physical conditioning prior to sleep deprivation? Does it, as many army leaders believe, and some psychologists suggest, delay cognitive degradation?

Hammerton and Tickner (1968) found a relationship between level of physical fitness and task performance after exercise (under normal sleep conditions). More specifically, that moderately fit research participants were not affected by exercise when required to perform a moderately difficult task, but showed a significant decrement on the difficult task. The high level fitness group did not show a decrement in task performance on either task. This indicates that the physiological arousal induced by the exercise did not exceed the optimum level in the very fit group. Although the experiment was not conducted under sleep deprivation, it does suggest that physical fitness may have a moderating effect on cognitive degradation when fatigued.

Hypotheses. Unfortunately, the psychological/physical fitness literature does not provide valid investigations upon which to answer the fitness/cognitive degradation question. Therefore, this investigation attempted to determine if there is a relationship between level of physical fitness and cognitive degradation during sleep deprivation. Based on the lack of empirical data relating to this area, this investigation was exploratory in nature with the purpose of suggesting some theoretical relationships. The basic hypothesis to be tested was that: The level of physical fitness will moderate cognitive degradation such

that individuals in the high fitness group will show less cognitive degradation during sleep deprivation than individuals in the low fitness group.

To test this hypothesis, the cognitive performance of research participants of varying levels of physical fitness was tested under conditions of sleep deprivation. A positive or negative finding will have significant implications for the military's physical fitness program in relation to sustained combat operations. Namely, that we need to raise the fitness level of all service members, or that physical fitness is not a variable of concern in delaying cognitive degradation during sustained combat operations.

CHAPTER 2

METHOD

Participants

The research participants were 16 male undergraduates enrolled in Advanced Military Science (ROTC) at the University of Georgia. The participants had received approval to take part in a Pre-Ranger Evaluation (PRE) exercise, the performance on which, would determine which of the participants would be nominated to attend the US Army Ranger school in lieu of ROTC Advanced Camp. One of the 16 participants was injured during the PRE and was unable to complete the exercise. His data were not included in the analysis.

Tests and Measurements

Three paper and pencil tests were used to assess cognitive performance during the PRE. They were:

TEST	TIME	APPENDIX
A (logical reasoning)	1 min	A
B (map plotting)	3 min	B
C (encoding/decoding)	6 min	C

Test A (Braddely, 1968; Haslam et al., 1977) measures the participant's ability to reason logically. In order to

measure logical reasoning, it requires the participant to read sentences of varying syntactic complexity and evaluate combinations of the letters "A" and "B" that follows. For example, "A does not follow B. ____AB."If the statement is true, then a check mark is placed in the blank that follows AB. If it is false, no response is made, and the participant continues on to the next sentence. Although other researchers using this test allowed six minutes to respond to the 16 items, only one minute was allowed during this investigation. The time was shortened based on the results of pilot tests which revealed that the population from which the sample was drawn could easily respond to the items in one minute.

Test B, map plotting, was a modification of the one used by Haslam et al. (1977). It consisted of a blank grid (12 x 17) with grid line identification numbers along the sides. The participants were required to plot eighteen 6-digit grid coordinates on the grid. This was identical to plotting grid coordinates on a military map. Three minutes were allowed to plot the grid coordinates.

Test C, encoding/decoding, (Dudley, 1972; Haslam et al., 1977) consisted of fifteen 6-digit grid coordinates and fifteen bigrammes (e.g., FGYJ). The participant was required to encode the grid coordinate, then decode the corresponding bigram using the code strip at the top of the page. Six minutes were allowed for completion of this test.

The above tests were administered seven times, four

prior to the start of the PRE, two during the PRE, and one 24 hours after the PRE. Seven parallel forms of the tests were used to avoid any possible learning of the response items.

Two subjective, paper and pencil measures of fatigue were used. The measures were made using the Tiredness Scale (Haslam, 1978; Appendix D) and the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Derment, 1973; Appendix D).

The Tiredness Scale consisted of a 25-point scale ranging from very fresh to very tired. The participant was required to circle a point on the scale indicating how tired he was at the time. The Sleepiness Scale was a seven point scale ranging from, "1. Feeling active and vital; alert; wide awake." to, "7. Almost in a dream; will be asleep soon; lost struggle to remain awake."

The "peer rating" has been shown (Downey, Medland, & Yates, 1976) to be an effective predictor of officer performance and, at ROTC level, an effective predictor of "job performance rating" (Thompson, 1980). To assess the perceived potential performance or leadership ability, a "peer rating" was made for each participant on day 7 (Appendix E). This consisted of having each participant rate, on a scale of 1 to 14 with 1 being the highest leadership potential, all of the other participants. Thus, the best possible average score was "1.0" and the worst possible average score was "14.0".

The physical fitness measures consisted of:

a. Resting pulse

b. Aerobic Step Pulse (Harvard Step Test: Appendix F)

c. Chinups

d. Advanced Physical Readiness Test (Modified)

The resting pulse was taken by a Naval Medical Corpsman for 10 seconds and multiplied by 6 to obtain the pulse per minute. The aerobic pulse was measured after five minutes of stepping up on and down from a 15 1/4 inch step at the rate of 90 steps per minute. The pulse was counted for a period of 15 seconds (Appendix F). The next measurement consisted of chinups, palms facing the participant. The participant was required to come to a dead hang, and, on the command of the experimenter, begin to pull himself up until his chin was above the bar, then come to a dead hang and repeat the exercise. Swinging the feet forward was not allowed.

The next event consisted of the Advanced Physical Readiness Test (APRT) (modified). The test was given on a local high school athletic track. The test was conducted as follows. The participants were instructed to assume the pushup starting position and to begin doing pushups when given the command to start. They were to complete as many pushups as possible during the two-minute time period. That is, they were to continue doing pushups even after they had completed enough to "max" the pushup event on the APRT. There was one grader per participant. The grader placed his fist perpendicular to the ground with the little-finger side

down and the thumb-side up. For a pushup to be counted, the participant's chest, between the pectoral muscles, had to touch the grader's fist. The number of pushups completed when the two minutes were up, or when the participant's knee touched the ground, was used as the pushup score.

Three minutes later, the participants were required to perform as many bent-legged situps as possible in the two minutes allotted, even if they surpassed the number required to "max" the situp event on the APRT. Three minutes after the situp event, the two mile run began. The run was conducted in fatigues and combat boots on a hard surface athletic 1/4 mile track. One participant developed stomach cramps and failed to complete the two-mile run.

Procedure

The participants in this experiment were members of the University of Georgia ROTC who were competing for nominations for Ranger school. The evaluative instrument designed to select the best applicants was the PRE (developed by the experimenter). The PRE was originally designed to present a very physically and mentally demanding 72-hour field training exercise similar to the most demanding field exercises that would be encountered during the US Army Ranger school. Additionally, the PRE presented the ideal situation in which to perform a field experiment to test the proposed hypothesis. Since the experimenter was

also the person responsible for selecting the nominees for Ranger school, the overt experimentation portion of the experiment was separated from the military exercise by using civilian experimenters to deal directly with the participants in all matters concerning the experiment. The participants were assigned code numbers and gave all questionnaires, tests, etc. directly to the civilian experimenters. This was necessary in order to help prevent any self-presentation tactics on the part of the participants. Thus, the author was seen by the participants as being solely involved in the military aspect of the exercise in which they were involved.

The present investigation covered a total period of seven days; 1600 hours Tuesday until 1600 hours Monday. The investigation was conducted in three phases; Phase I, a control period (Days 1-3), Phase II, an experimental period (Days 4-6), and Phase III, a recovery period (Day 7).

Phase I began on a Tuesday with a briefing of participants as to generally what would take place during the next 7 days. At 1600 hours on Day 1, the first Cognitive Battery (Tests A, B, & C) was administered. The instruction was read aloud by an experimenter (civilian) for each test before the participants began. The order of presentation of the tests was always the same; Test A (logical reasoning), Test B (map plotting), and Test C (encoding/decoding). The specific versions of the tests to be given were selected using a Greco-Latin Square design that prevented any more than three

participants to be taking the same version of any one test during the same testing session. This effectively controlled for sequence and order effects. The control period was necessary to control for "learning effects" experienced when taking the same type of test several times.

Days 2 and 3 consisted of the participants taking Cognitive Batteries 2 and 3, respecively, at 1600 hours. Day 3 ended with the administration of Cognitive Battery 4 at 1600 hours on Friday.

Immediately following the completion of Cognitive Battery 4, Phase II began. The first subjective measure of fatigue was made by administering the Tired/Sleepy Questionnaire (TSQ). As soon as TSQ 1 had been completed, the physical fitness measures were made. The participants received their operations order at 1800 hours and began planning their field operation.

During Day 4-6, the leadership roles were changed at regular intervals, such that everyone was evaluated several times as the patrol leader. The participants took part in a continuous operation that consisted of planning, patrolling, ambushes, raids, land navigation, military skills testing (e.g., first aid, NBC, weapons, etc.), map reading diagnostics, and oral examinations (Appendix G). During this period, they were only allowed to sleep for two hours (Day 5, 2100-2300 hours). In addition to the above, the participants were only allowed one C-ration meal daily and stressed psychologically.

The PRE portion of the investigation ended after completion of Cognitive Battery 6 and TSQ 3 at 1600 hours on Sunday. The participants were then delivered to their dorms to begin Phase III, recovery. At 1600 hours on Day 7 the participants completed Cognitive Battery 7, TSQ 4, a post-experimental questionnaire (Appendix H), and the Peer Rating.

CHAPTER 3

RESULTS

Performance Stability

The purpose of Phase I (control period) was to allow performance on the cognitive tests to stabilize. Thus, the first step in the data analysis was to establish the stability of the performance on the cognitive tests prior to the experimental phase. To accomplish this, Day 2 was taken as the "base day" for comparing the performance (number correct; number attempted) on Days 3 and 4 on each of the three cognitive tests.

The correlations (Table 3) indicated that, with the exception of the number attempted on the logical reasoning test, performance had stabilized prior to the beginning of the experimental phase. Performance stability was based on the overall equality of the correlations across time (r23, r24), for each of the three tests.

Figure 4 depicts the three tests graphically as percent correct (to use a common scale) and shows the expected learning curve and the increasing stability during the control period.

Physical Fitness

A Pearson Product Moment correlation was performed on the physical fitness measures (Table 4). Surprisingly, all

Table 3

Intercorrelations Between Measures of Cognitive Performance on Day 2 and Performance On Days 3 and 4

	$r_{2,3}$	$r_{2,4}$
Logical Reasoning		
Number Attempted	.ØØ1	-.14
Number Correct	.60*	.81*
Map Plotting		
Number Attempted	.91*	.89*
Number Correct	.82*	.8Ø*
Encoding/Decoding		
Number Attempted	.74*	.77*
Number Correct	.94*	.78*

* p<.Ø5

SLEEP2/DIF
16/11/82

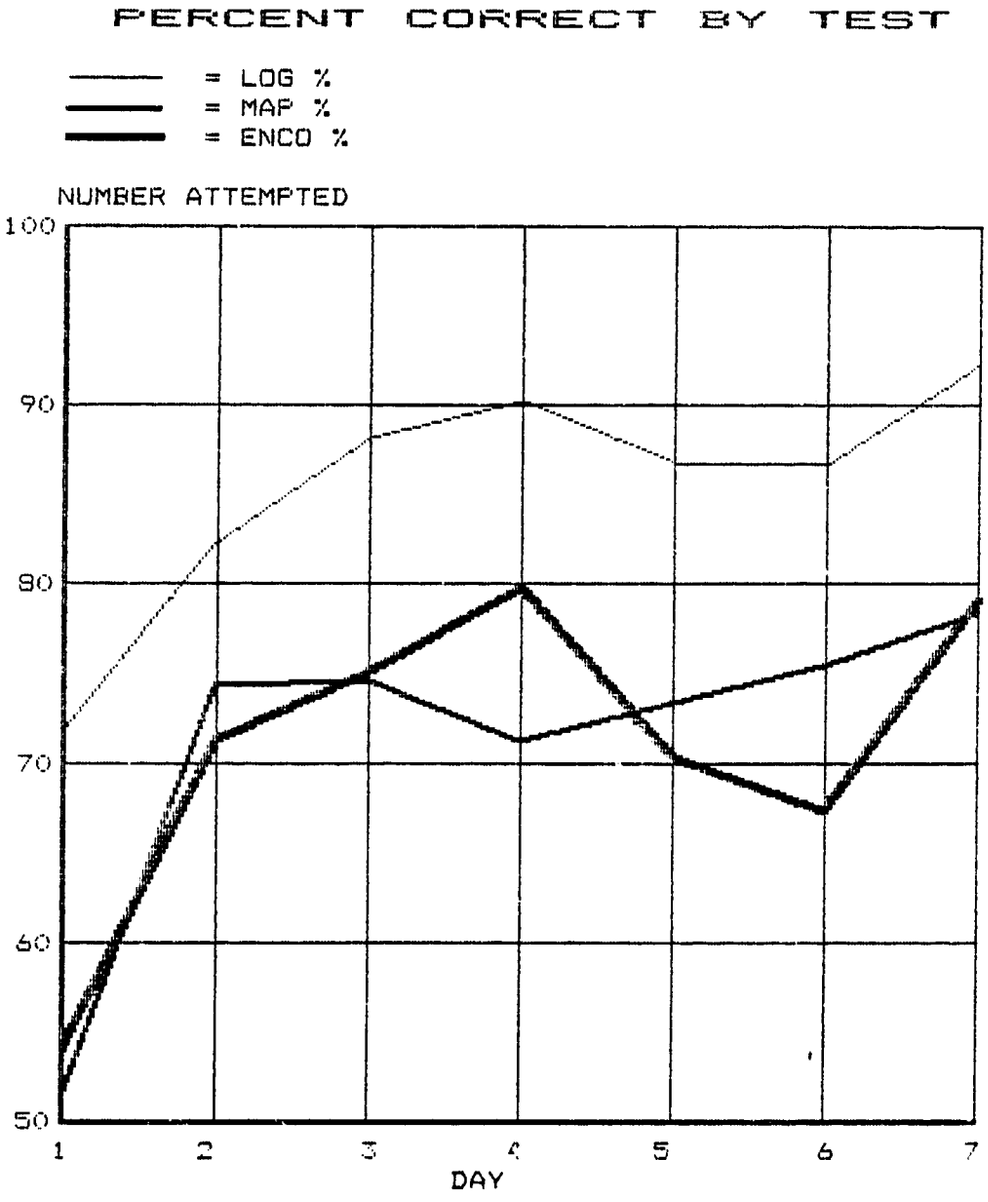

Figure 4

of the fitness measures did not correlate significantly with each other. The pushups, situps, chinups, and two-mile run were significantly, $p < .05$, (except chinups and situps, $p < .06$) correlated. The resting pulse and Harvard Step pulse did not correlate significantly with any of the other measures .

The physical fitness measures taken prior to the experimental phase provided several alternatives for operationally defining the physical fitness construct. Consequently, three fitness constructs were chosen as the basis of independent analysis; a Superfitness score, the APRT, and an Aerobic score (two-mile run time).

It should be noted that the justification for choosing three different stratifications (Superfitness, APRT, Aerobic) of the Fitness Group variable was the exploratory nature of the investigation. The results of the three sets of analyses cannot be combined. Thus, in the end, one of the three Fitness Group stratification criteria must be chosen over the others.

The Superfitness score was obtained by transforming step pulse, chinups, pushups, situps, and two-mile run scores into z-scores. The z-scores were then converted into centiles based on the percentage of the area they occupied under the normal curve. The centiles were summed and divided by 5 to provide an average score on the Superfitness scale . It was felt that a combination of all of the events would

Table 4

Intercorrelations Between Physical Fitness Measures

	Resting Pulse	Step Pulse	Chinups	Pushups	Situps	2-mile Run
Resting Pulse		.15	-.42**	-.36	-.23	.12
Step Pulse			.28	-.12	-.22	.29
Chinups				.70*	.40*	-.55*
Pushups					.71*	-.67*
Situps						-.80*

* $p<.01$ (one-tailed test)
** $p<.06$ (one-tailed test)

produce a more complete fitness construct.

The second fitness construct used was the score on the APRT. Although this score is composed of fewer measurements (specifically, step pulse and chinups) than the superfitness score, it was considered to be worth evaluating since the APRT is a standard army test required of everyone under 40 years of age, twice yearly. It would be very convenient if this measure was capable of predicting cognitive performance under sleep deprivation conditions. It should be noted, however, that the APRT events were modified, as previously described, to avoid a "ceiling effect." Therefore, the scoring had to be modified accordingly. Close examination of the the APRT scoring table (Appendix I; Table 10) reveals that each repetition of the the situp or pushup, after 58 repetitions, is worth two points. Thus, two points were allowed for each repetition completed beyond those shown in the APRT scoring table. Consequently, an individual could score higher than 300 points. (The highest score was 340.)

The third fitness construct was an aerobic measure; the two-mile run. The step pulse, although considered a good indicator of aerobic conditioning, did not correlate significantly with any of the fitness measures, including the two-mile run. Therefore, for the purposes of this investigation, the two-mile run was used as the indicator of aerobic conditioning. If the Aerobic score (two-mile run time) proved to be a good predictor of cognitive performance under sleep deprivation, it would lend additional credence

to the daily PT runs.

Research participants in each of the groups above were assigned to Fitness Level categories by the following method. The top 33% in each group were categorized as "above average (AA)," the middle 33% as "average (AV)," and the bottom as "below average (BA)." This resulted in the Fitness Levels having different numbers of participants in them (Superfitness Group, AA=4, AV=8, BA=3; APRT Group, AA=7, AV=5, BA=3; Aerobic Group, AA=4, AV=6, BA=5).

Physical Fitness and Cognitive Performance

To assess the performance differences between the Fitness Levels of a Fitness Group, a 3 (Fitness Level) x 4 (Day) factorial multivariate analysis of variance (MANOVA), with Day as a repeated factor, was performed on each of the Fitness Groups. Fitness Level was the between groups factor and Day (5-7) was the within groups factor. The dependent variables for the MANOVAs were the number correct and number attempted for each test (6 dependent variables).

In an A x B factorial design in which there is no A x B interaction, significant main effects of the A and B variables may be examined directly through the use of standard post hoc tests, e.g., Newman-Keuls, Tukey, etc. (Keppel, 1973). In the case of this investigation, significant main effects were tested, where allowed, by the Newman-Keuls Multiple Range test (Tables - ; Appendix). The only significant main effect was for the Day variable. Since

Day was a repeated factor, the following equation was used to compute the "critical difference" for testing the significance of the effect.

$$CR_{N-K} = q(r, df_{S/AB}) \sqrt{\frac{MS_{S/AB}}{n}}$$

Another consideration was the unequal numbers of participants in each group. To account for this, the harmonic cell mean was substituted for the arithmetic mean in the above equation (Winer, 1971). The harmonic means were computed as follows.

a. $n = \frac{\text{number of groups}}{1/n + 1/n + \ldots + 1/n}$

b. $n_{superfit} = \frac{3}{1/4 + 1/8 + 1/3} = 17.00$

c. $n_{APRT} = \frac{3}{1/7 + 1/5 + 1/3} = 17.83$

d. $n_{aerobic} = \frac{3}{1/4 + 1/6 + 1/5} = 19.45$

Analyses involving Fitness x Day interactions required a slightly different approach. Specifically, the MS error term used to derive the standard error was a "pooled" error term (see Winer, 1971, pp. 529-532 for a detailed treatment of this technique).

$$MSw\text{-}cell = \frac{SSw\text{-}cell}{pq(n-1)}$$

Although each of the dependent variables produced the expected significant main effects of Day, this investigation was primarily concerned with the Fitness x Day interaction. Thus, only the interaction effects will be discussed in detail. The results of all of the analyses are presented in tabular form in the Appendices.

All three Fitness Group MANOVAs failed to show a significant main effect for Fitness Level (Appendix J). The only significant Fitness Level x Day interactions were in the Superfitness Group (Map plotting, number correct, $F(6,36)=2.88$, $p<.02$; Encoding/Decoding, number correct, $F(6,36)=2.59$, $p<.04$) and the APRT Group (Map plotting, number correct, $F(6,36)=2.33$, $p<.05$) (Figures 5, 6, & 7). To further assess the affect of these variables, post hoc analyses of the simple interaction effects of these three variables were conducted. A significant (Pillai's Trace) main effect for Day was obtained for each Fitness Group; Superfitness, $F(18,99)= 2.52$, $p<.00$; APRT, $F(18,99)=2.43$, $p<.00$; Aerobic $F(18,96)=2.73$, $p<.00$. Due to the results of the Fitness Group analyses, each will be discussed separately.

Superfitness. There were no differences during Days 4, 5, and 6 for Map Plotting: Number correct. Day 7 (recovery), however, did show differences (Figure 5). Specifically, the Average Fitness Level ($X=4.13$) scored significantly ($p<.05$)

SUPER2/DIF
17/11/82

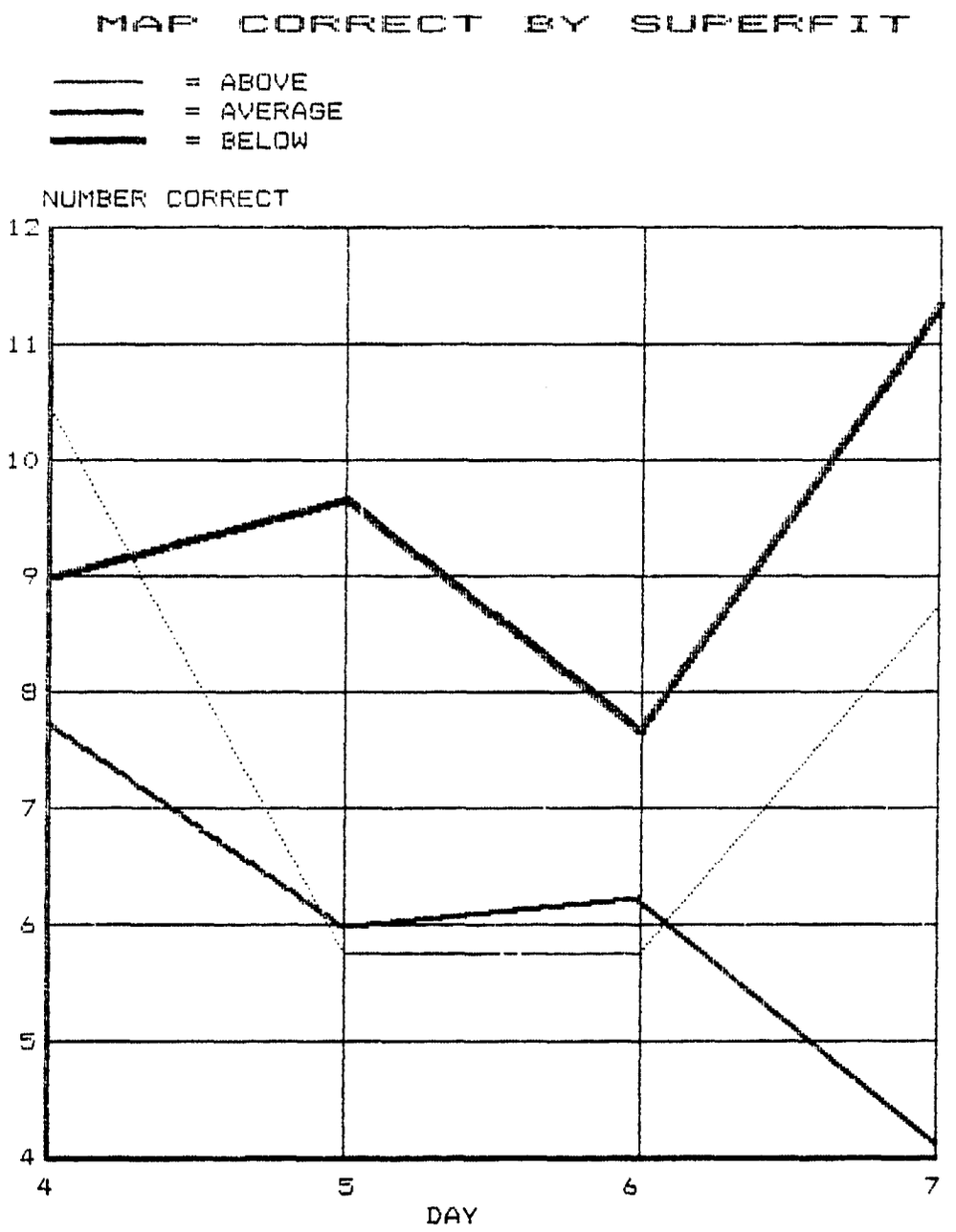

Figure 5

fewer correct than did the Above Average (X=8.75) and the Below Average (X=11.33) Fitness Levels. In fact, the Average Fitness Level actually made a sharp decline on Day 7 while the other two Levels increased in Number correct.

The Encode/Decode: Number correct (Figure 6) showed a decline for all three Fitness Levels across Days 5 and 6 with the Above Average Level (X=11.ØØ) scoring a significantly ($p<.Ø5$) greater Number correct on Day 6 than the Below Average Level (X=8.ØØ). On Day 7, both the Above Average (X=15.25) and the Below Average (X=14.ØØ) Levels uncreased significantly ($p<.Ø5$) above the Average Fitness (X=9.25) Level in Number correct.

APRT. The only significant ($p<.Ø5$) Fitness Level x Day interaction in this Group was for Map Plotting: Number correct (Figure 7). There were no differences at Day 4 or 6. At Day 5, the Below Average Level (X=9.67) scored significantly ($p<.Ø5$) more correct than the Above Average (X=5.ØØ). Day 7 revealed that the Below Average Level (X=11.33) scored significantly ($p<.Ø5$) more correct than either the Above Average (X=6.71) or the Average (X=4.2Ø) Level.

Aerobic. The Aerobic Fitness Group did not produce any significant Fitness Level x Day interactions for the cognitive tests.

The most promising data, from a Fitness Group perspective, occurs with the Encode/Decode variable (Figures

SUPER3/DIF
17/11/92

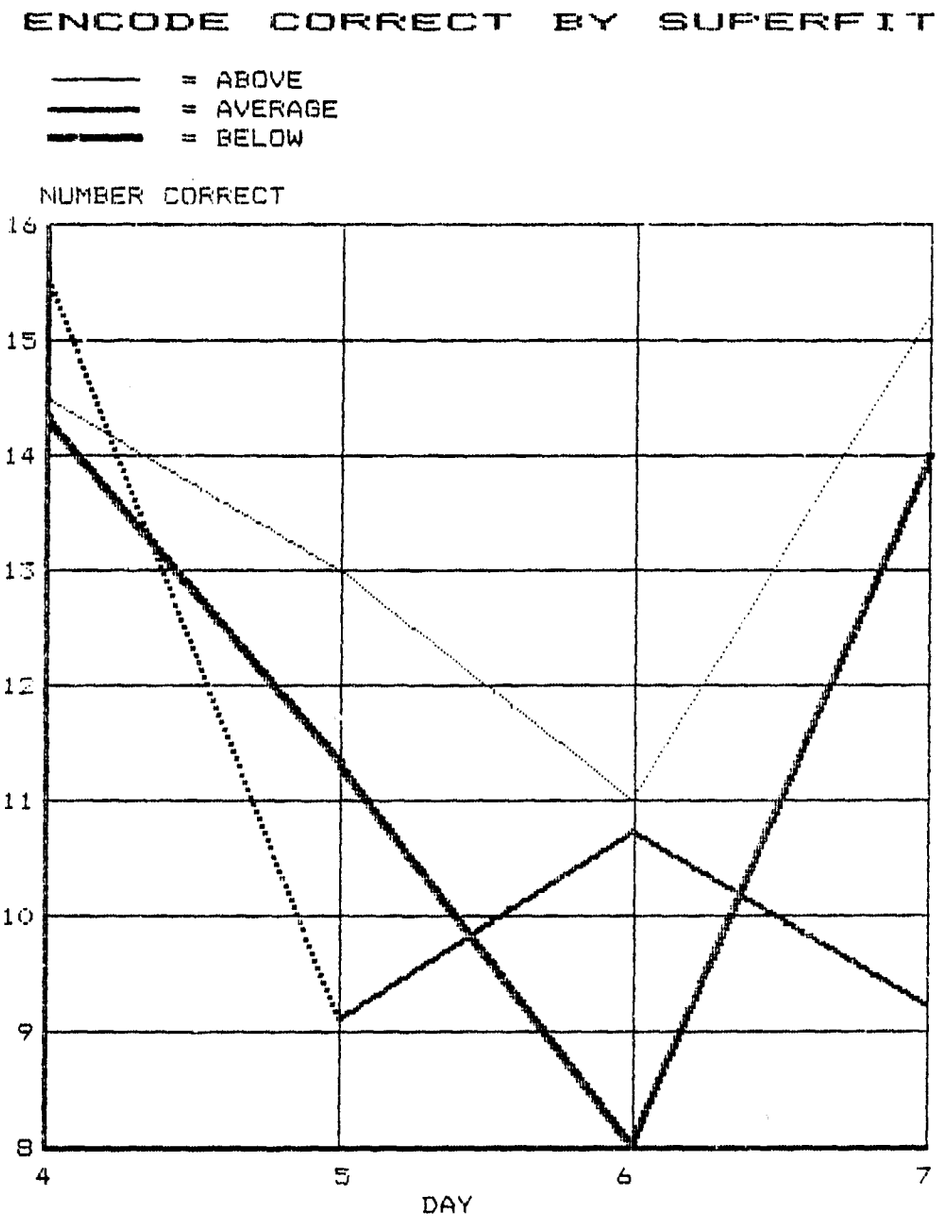

Figure 6

SLEEP15/DIF
16/11/82

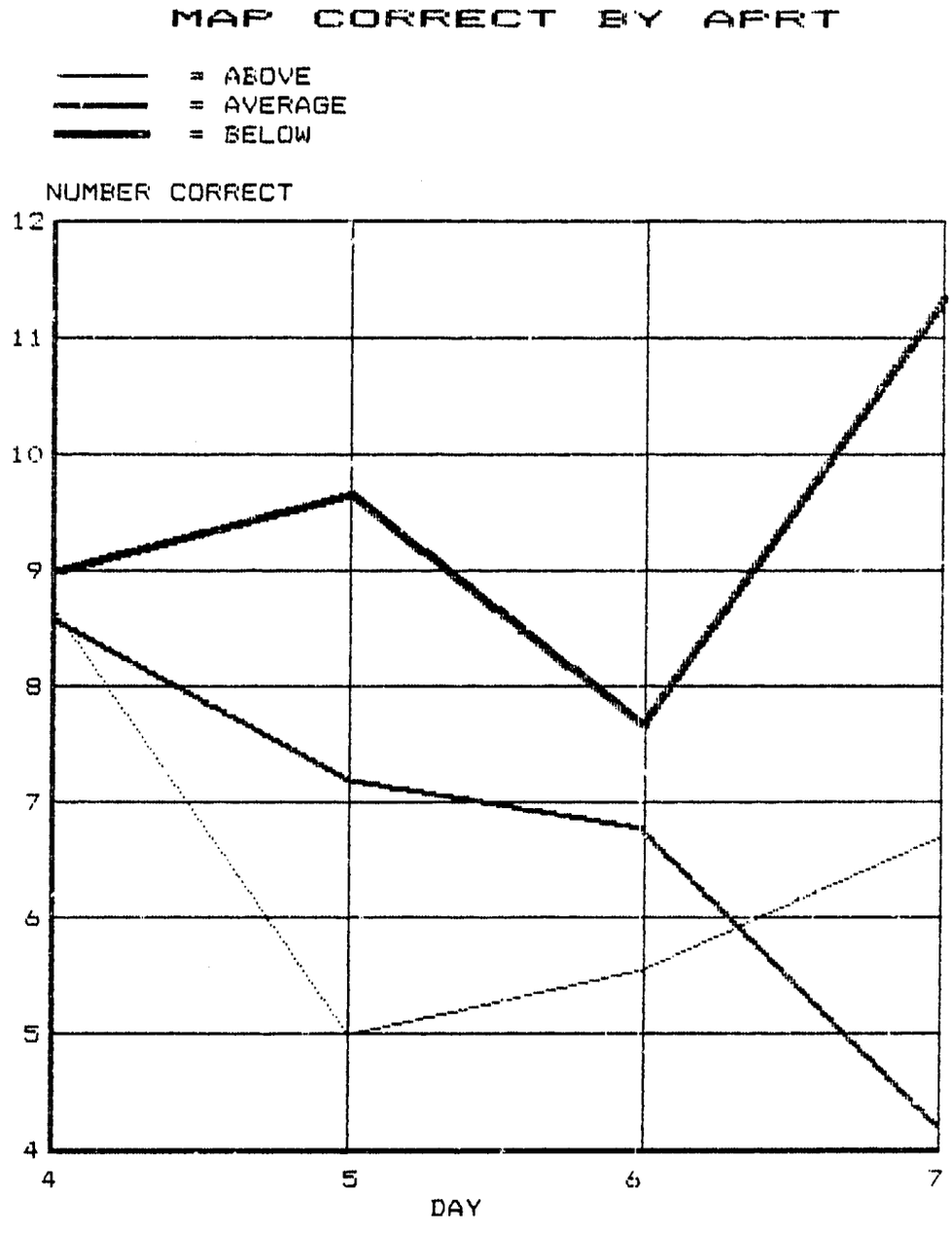

Figure 7

SLEEP17/DIF
16/11/82

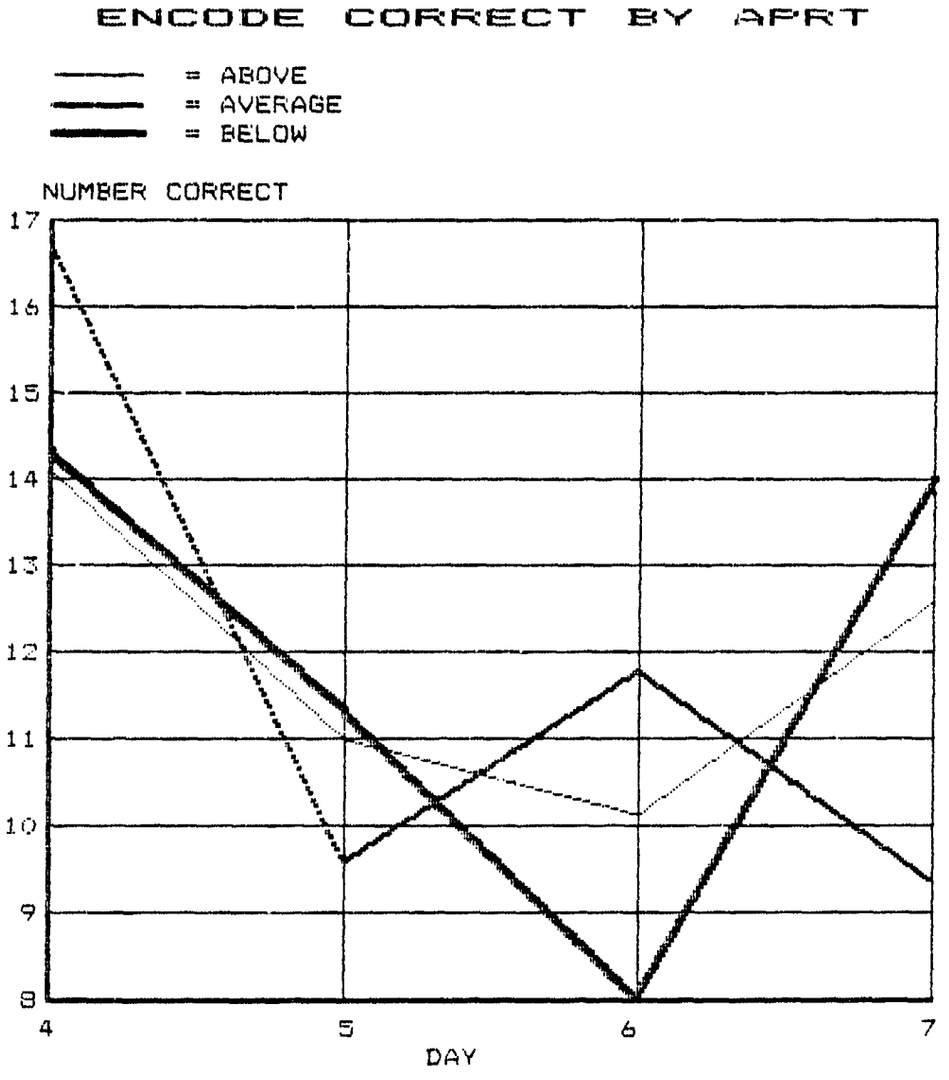

Figure 8

9-11. It can be seen that the Above Average Fitness Levels showed a less extreme drop in performance (although not statistically significant) than the other Fitness Levels. This was true in all three Fitness Groups (except Aerobic Encode/Decode: Number Attempted).

The strong effect of Day indicates the powerful effect of sleep deprivation on cognitive performance. Visual inspection of the mean performance by test by Day (collapsed across Fitness Groups and Levels) shows the continued decline in performance as the sleep deprivation increased (Table 5). Post hoc analyses (Newman-Keuls) of these means indicated that Day 5 was significantly ($p<.05$) different from Day 4 and Day 7 on both number correct and number attempted on each of the three tests. Days 5 and 6 were not statistically different.

The 24 hour rest period resulted in a significant ($p < .05$) increase in performance. It appears, in general, that 24 hours of rest completely rejuvenated the participant's ability to perform the cognitive functions required by the tests (except the number attempted on the logical reasoning and map plotting tests).

Physical Fitness and Fatigue

Fatigue was measured using two subjective scales, tiredness and sleepiness. The fatigue measurements were taken at 1600 hours on Days 4-7. Table 6 lists the fatigue scale Day means and deviations by Day collapsed across

SLEEP18/DIF
16/11/82

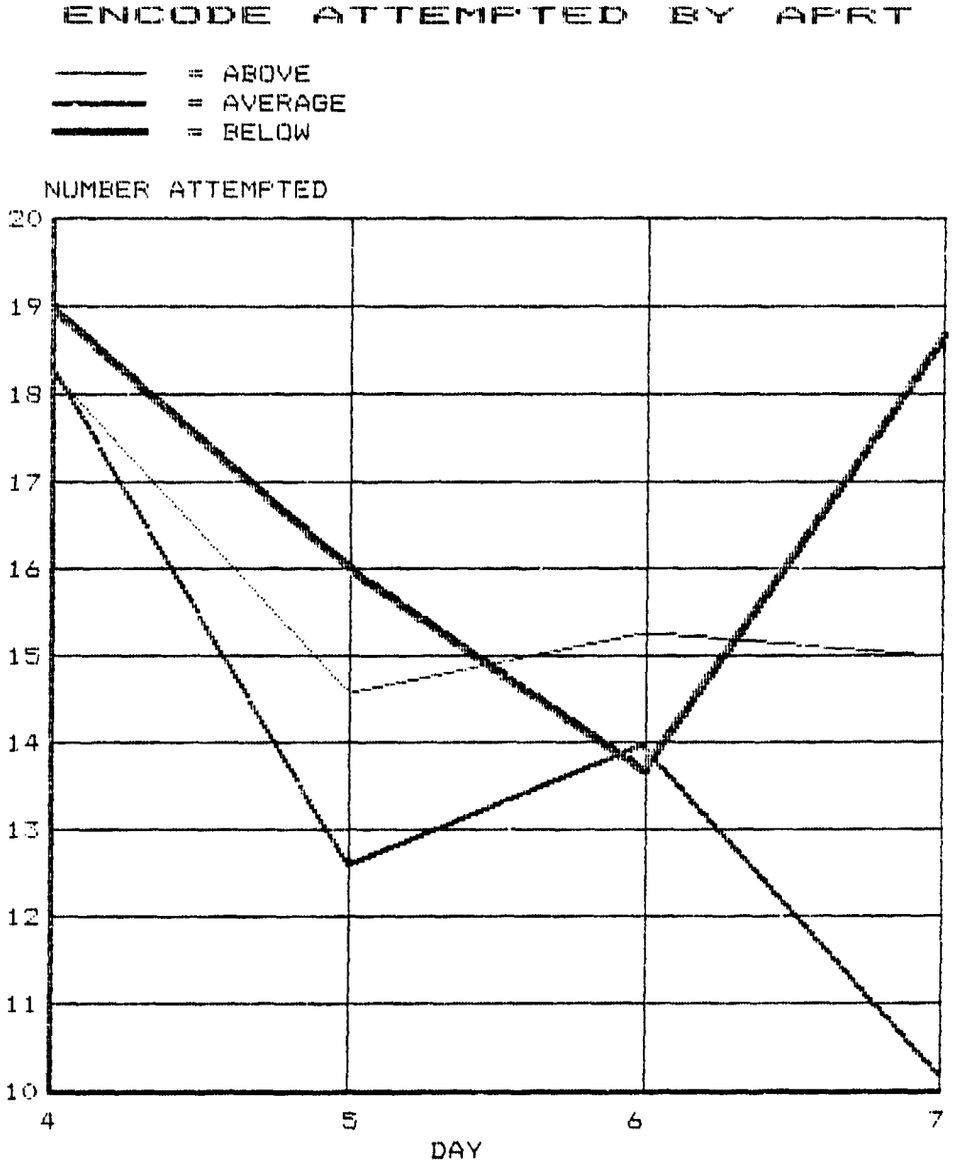

Figure 9

SLEEP23/D1F
16/11/82

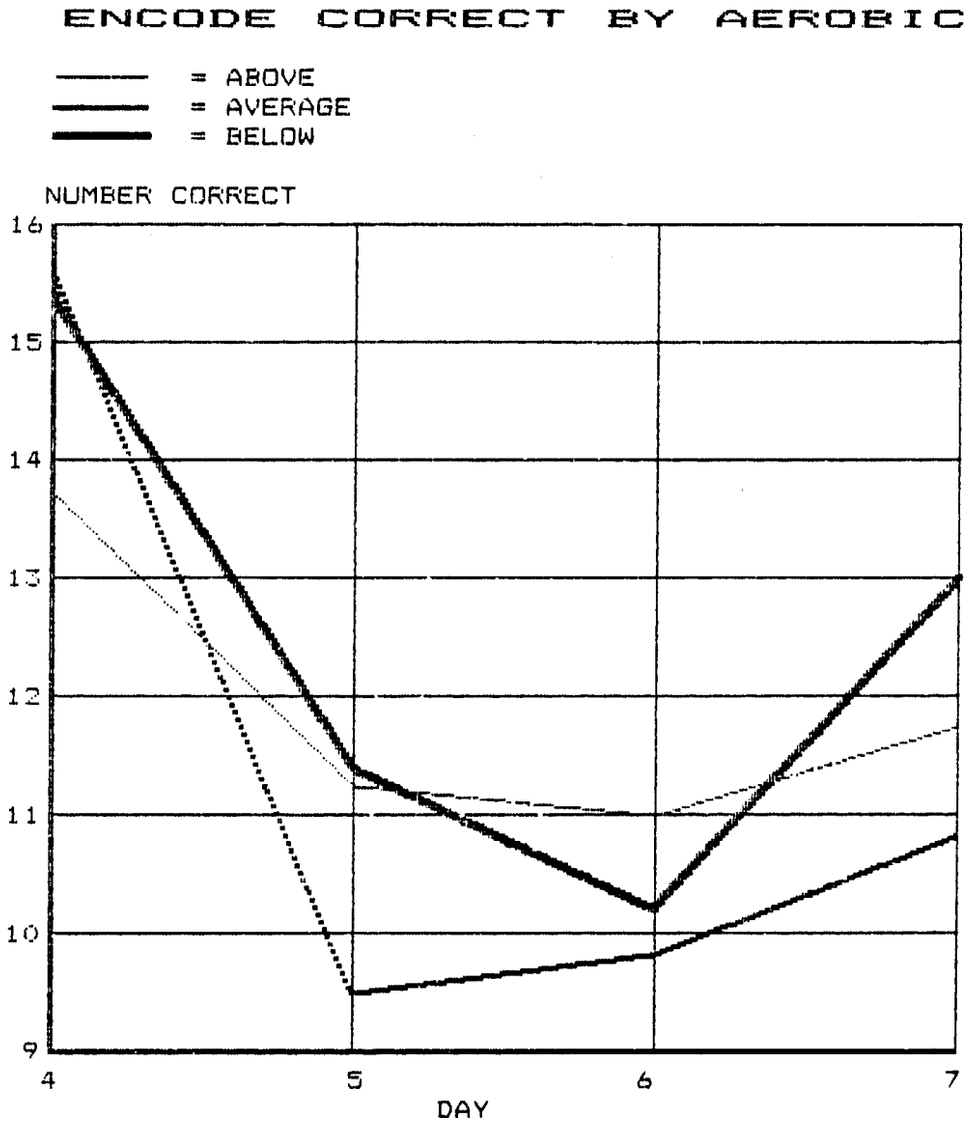

Figure 10

SLEEP24/DIF
16/11/82

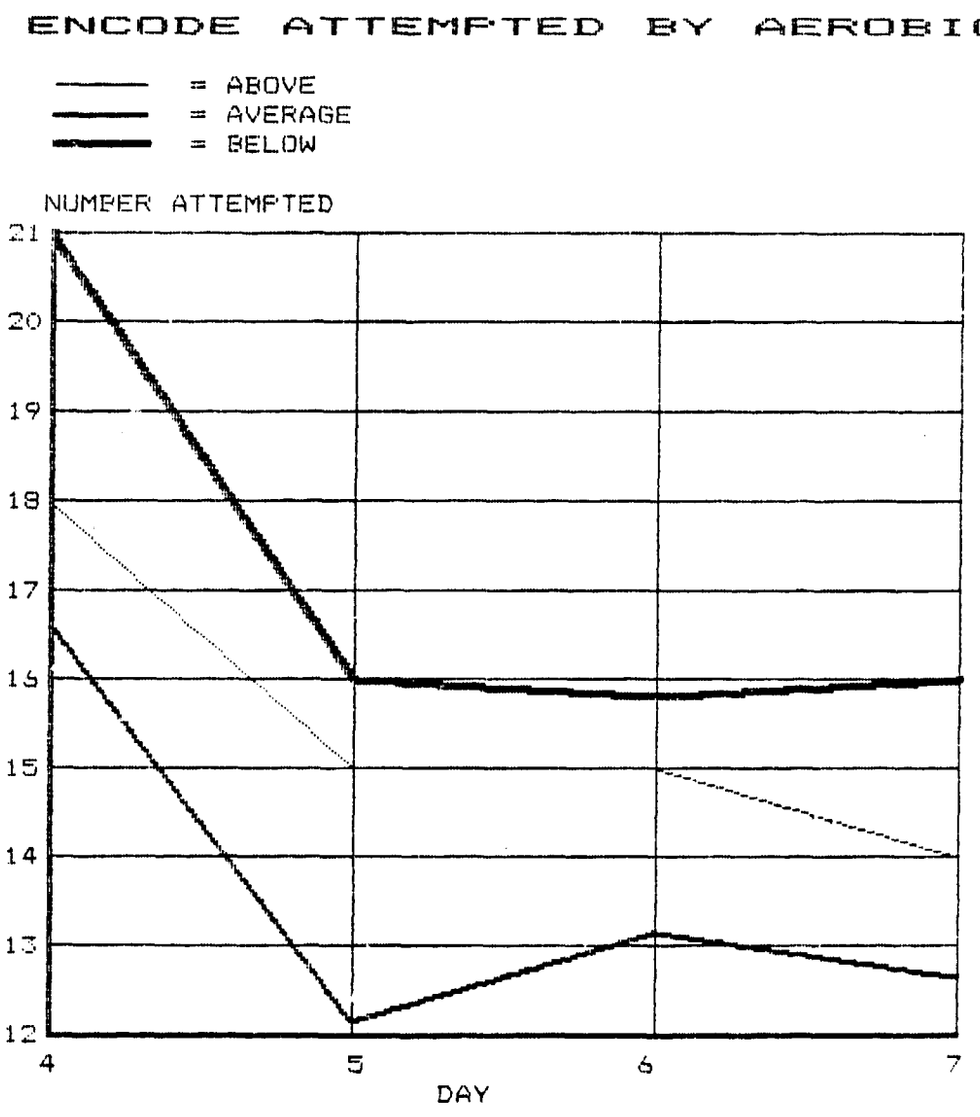

Figure 11

Table 5

Means and Standard Deviations for Cognitive Measures Across Days (Fitness Groups Combined)

		Day			
		4	5	6	7
Logical Reasoning No. Attempted	M	15.42	13.17	13.92	13.92
	SD	1.16	2.44	1.62	1.68
Logical Reasoning No. Correct	M	13.83	11.75	12.33	12.83
	SD	2.98	4.11	3.23	2.12
Map Plotting No. Attempted	M	14.00	10.30	9.60	12.60
	SD	2.70	3.80	2.63	3.92
Map Plotting No. Correct	M	10.90	8.00	7.90	10.20
	SD	3.96	3.46	3.48	4.10
Encode/Decode No. Attempted	M	18.67	15.00	14.75	17.67
	SD	4.77	4.04	4.92	5.55
Encode/Decode No. Correct	M	15.75	11.92	10.83	14.75
	SD	7.27	6.08	6.46	7.53

Fitness Groups and Levels. A 3 (Fitness Level) x 4 (Day) analysis of variance (ANOVA) with repeated measures on Day, was performed on each of the Fitness Groups. Significant effects were obtained.

Superfitness. The Superfitness Group produced a significant Fitness Level x Day interaction on both the Tiredness scale, $F(6,36)=2.59$, $p<.04$, and the Sleepiness scale, $F(6,36)=3.45$, $p<.00$ (Figures 12 & 13). The simple interaction analysis revealed that, although the three Fitness Levels reported essentially the same Tiredness Levels on Day 4, the Below Average Fitness Level (X=6.00) eported feeling significantly ($p<.05$) less tired on Day 5 than the Above Average (X=16.25) and Average (X=16.50) Levels. By Day 6, the three Fitness Levels were once again equivalent on the Tiredness scale and remained so through Day 7.

As with the Tiredness scale, the Fitness Levels were not different on the Sleepy scale on Day 4. On Day 5, the Average Level (X=3.75) reported being significantly ($p<.05$) more sleepy than either the Above Average (X=2.5) or Below Average (X=2.33) Levels. By Day 6, the Below Average (4.00) and Average (X=2.75) Levels had reversed. That is, the Below Average Level reported being significantly ($p<.05$) more sleepy than the Average Level. On Day 7, the Above Average Level (X=2.25) reported being significantly ($p<.05$) more sleepy than the Average (X=1.13) and Below Average (1.33) Levels.

Table 6

Means and Standard Deviations for Fatigue Ratings Across Days (Fitness Groups Combined)

		Day 4	5	6	7
Tiredness Scale	M	7.92*	14.08	11.33	6.75
	SD	4.03	5.93	5.51	3.96
Sleepiness Scale	M	2.25	3.33	3.17	1.83
	SD	.62	.89	.94	.94

*Larger numbers indicate increasing levels of fatigue.

TIRED3/DIF
16/11/82

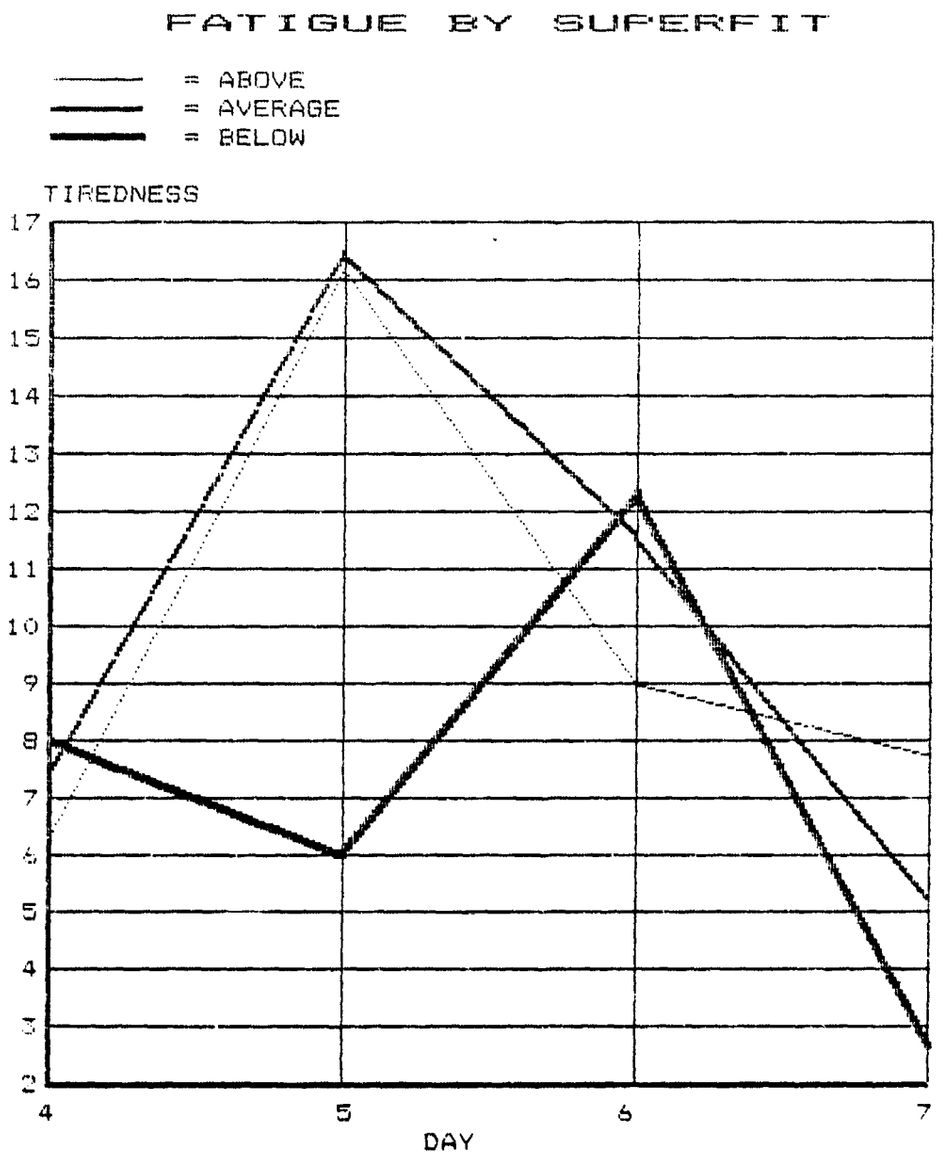

Figure 12

SLEEPY3/DIF
16/11/82

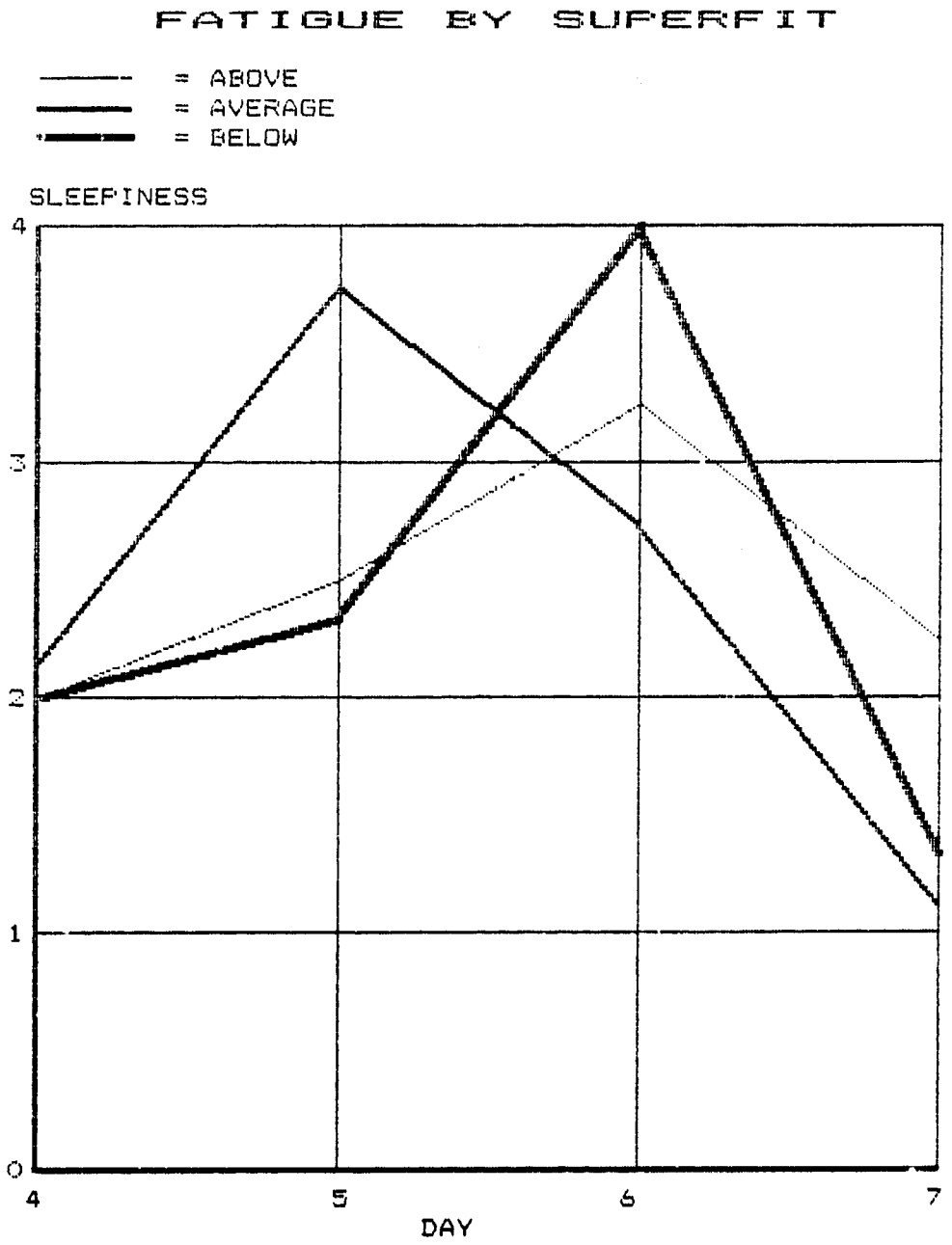

Figure 13

APRT. The APRT Fitness Group produced a significant, $F(6,36) = 2.37$, $p < .05$, Fitness Level x Day interaction on the Tiredness scale (Figure 15). Analyses indicated that the Below Average Fitness Level (X=6.00) reported being significantly ($p < .05$) less tired on Day 5 than the Average (X=15.6) and the Above Average (X=17.00) Fitness Levels. The Fitness levels were not different on the other Days. Day 5 was significantly ($p < .05$) different from Days 4, 6, and 7.

The Sleepiness variable only produced a main effect $F(3,36)=10.15$, $p < .00$, of Day for the APRT Fitness Group (Figure 15). Post hoc analysis indicated that Day 6 was significantly ($p < .05$) different from Days 4, 5, and 7.

Aerobic. The Aerobic Fitness Group had a significant, $F(3,36)=13.71$, $p<.00$, main effect of Day (Table 7; Figure 16) on the Tiredness scale. Post hoc analysis indicated that Day 5 was significantly ($p < .05$) different from Days 4, 6 and 7.

The Sleepiness scale produced a significant, $F9(6,36)= 2.98$, $p<.02$, Fitness Level x Day interaction (Figure 17). Analyses indicated that the Above Average Fitness Level (X=2.50) was less sleepy ($p < .05$) than the Average Fitness Level (X=3.67) on Day 5 and that the Average Fitness Level (X=2.33) was less tired ($p < .05$) than the Below Average (X=3.8) and Above Average (X=3.50) Fitness Levels on Day 6. There were no differences on Day 7. Days 5 and 6 were different ($p < .05$) from Days 4 and 7.

The above analyses did not provide support for previous

TIRED1/DIF
16/11/82

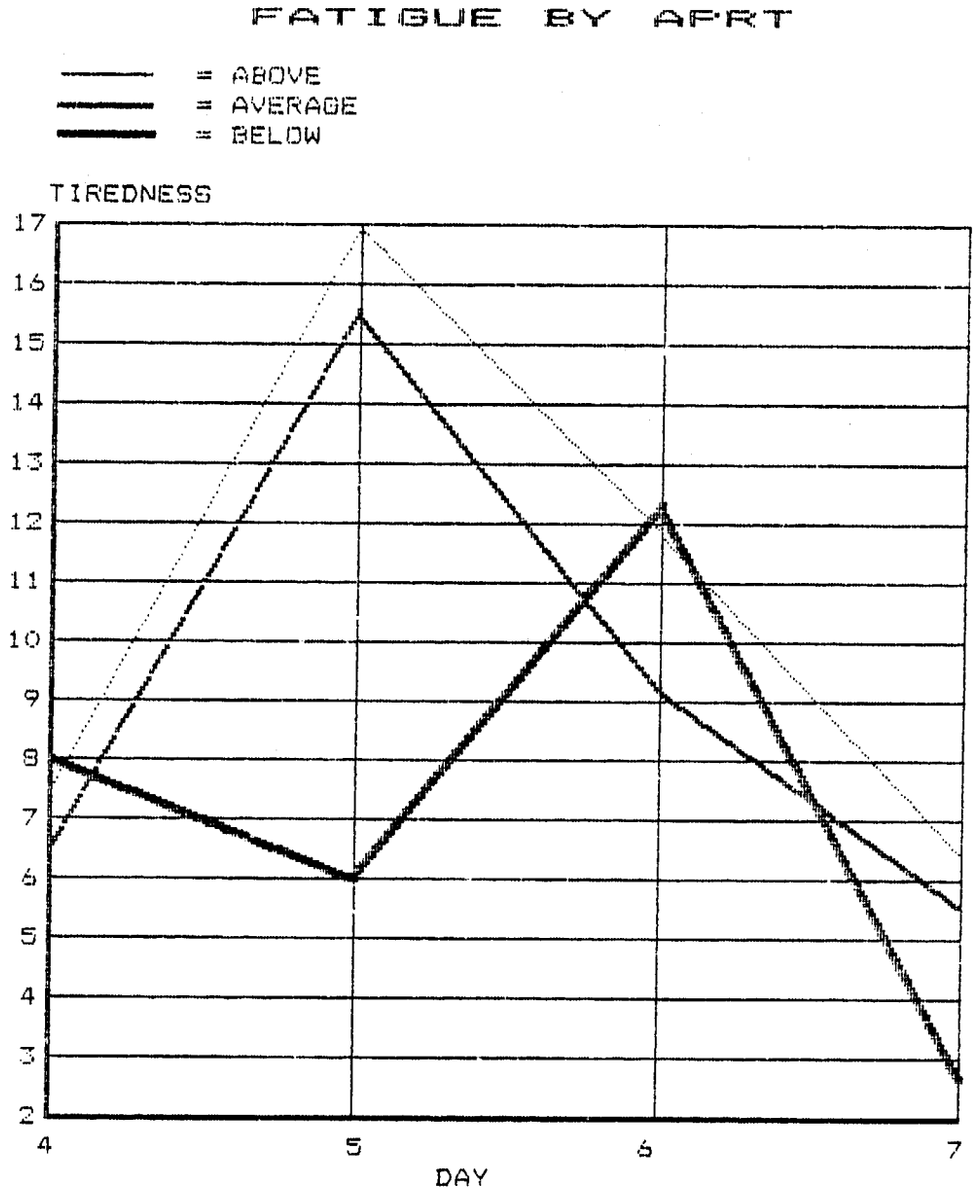

Figure 14

SLEEPY1/DIF
16/11/82

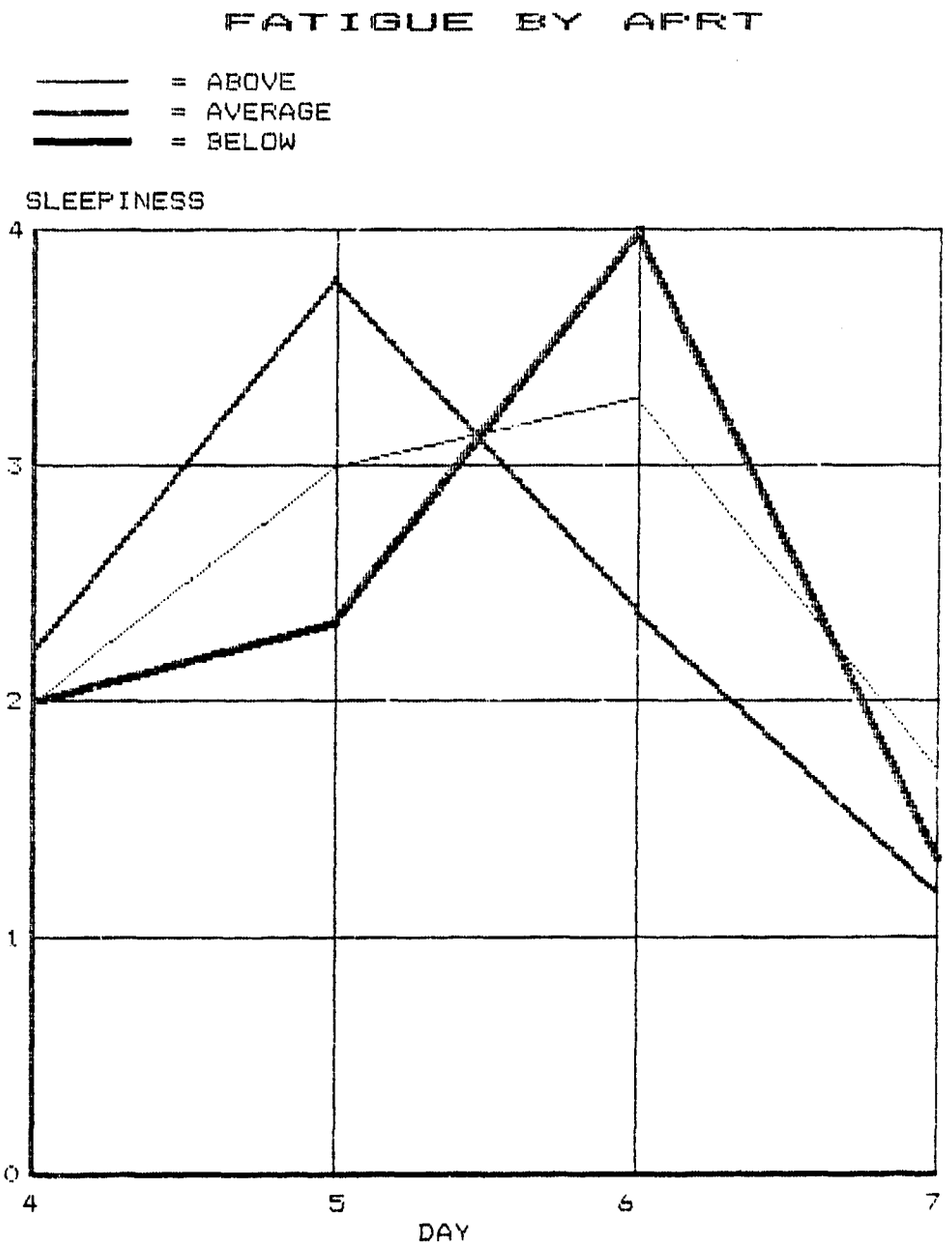

Figure 15

TIRED2/DIF
15/11/82

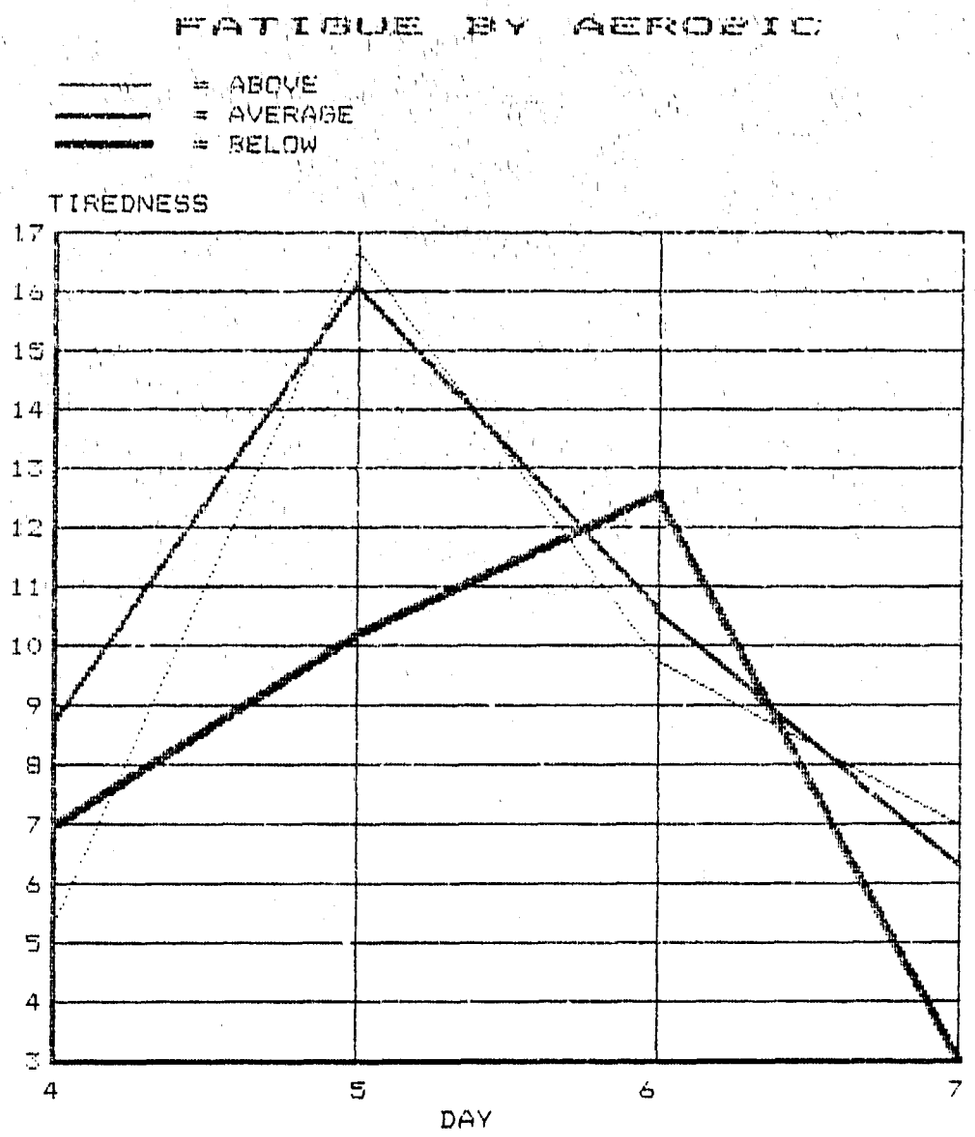

Figure 16

Table 7a

Correlations Between Fitness and Fatigue Measures for Day 4

	Resting Pulse	Step Pulse	Chinup	Pushup	Situp	2-Mile
Tiredness Scale	-.35	-.12	.12	-.02	-.10	.18
Sleepiness	-.42	-.18	.10	-.01	-.01	.02

Table 7b

Correlations Between Fitness and Fatigue Measures for Day 5

	Resting Pulse	Step Pulse	Chinup	Pushup	Situp	2-Mile
Tiredness Scale	-.42	-.01	.53	.61	.74	-.66
Sleepiness	-.69	-.19	.29	.32	.51	-.53

Table 7c

Correlations Between Fitness and Fatigue Measures for Day 6

	Resting Pulse	Step Pulse	Chinup	Pushup	Situp	2-Mile
Tiredness Scale	-.28	.13	.15	-.01	-.19	.12
Sleepiness	.19	-.21	.18	-.07	-.38	.10

Table 7d

Correlations Between Fitness and Fatigue Measures for Day 7

	Resting Pulse	Step Pulse	Chinup	Pushup	Situp	2-Mile
Tiredness Scale	-.47	-.03	.60	.43	.56	-.49
Sleepiness	-.31	-.12	.59	.35	.25	-.34

SLEEPY2/DIF
16/11/82

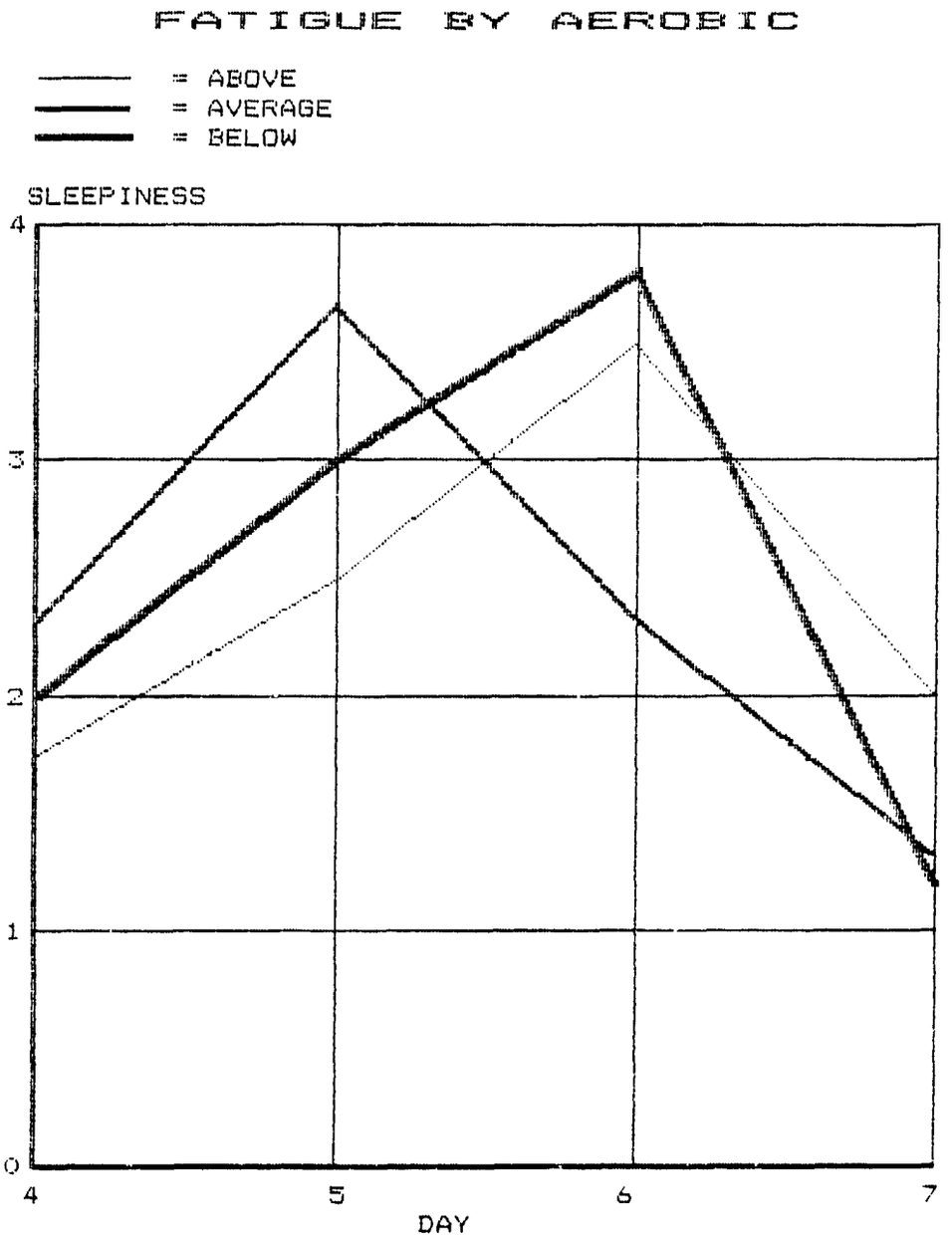

Figure 17

hypotheses that physical fitness moderates the onset of fatigue. Thus, one other type of analysis was performed on the fatigue data. This was a Pearson Product Moment correlation between the original fitness measures and reported fatigue level for Days 4-7. Due to the nature of the measurements, it was expected that the step pulse and two-mile run would correlate positively, and that chinups, situps, and pushups would correlate negatively with fatigue. Table 7 indicates that the measures were not significantly correlated with the two fatigue scales.

Physical Fitness and Leadership

The last area to be assessed was perceived leadership ability as moderated by physical fitness. Pearson Product Moment correlations were computed between the "peer rating" each participant received and the fitness measures (Table 8). The results indicated that participants who were perceived as having high leadership ability did more chinups, $p < .00$, pushups, $p < .03$, situps, $p < .03$, and ran faster, $p < .07$ (all one-tailed tests) than did those participants perceived to have low leadership ability. Additionally, those with low step pulses were associated with low leadership ability.

Table 8

Correlations Between Peer Ratings and Physical Fitness Measures

	Resting Pulse	Step Pulse	Chinup	Pushup	Situp	2-Mile
Peer Rating	-.11*	-.40	-.65	-.48	-.48	.41

NOTE: The lower the numerical score on the peer rating, the greater the perceived leadership ability. The higher the numerical score on the physical fitness scores, the higher the performance (except the 2-mile run time). Thus, negative correlations (except for the 2-mile run) indicate that the better a participant performed on a physical fitness measure, the higher his perceived leadership ability.

CHAPTER 4

DISCUSSION

The literature reviewed indicated that sleep deprivation has some very predictable affects on human performance. Given that the outcome of future wars may be determined in a relatively short time due to the continuous nature of the combat, there manifests a need to identify variables that will significantly influence performance during sleep loss. Thus, this investigation attempted to evaluate one such variable, physical fitness.

Fitness Measures

One finding that was inconsistent with the current literature was that the aerobic measures did not correlate significantly. That is, resting pulse, Harvard step pulse, and the two-mile run times were not correlated. A possible explanation for this may be that the highly variable, human heart rate may have been hyper-elevated due to the individual differences in reaction to evaluation apprehension resulting from the upcoming Ranger Pre-evaluation. This explanation is supported by the relatively inconsistent pulse rates across individuals and low correlation with the fitness measures.

Groups.

Although the data were stratified into three different

Fitness Groups, there was no advantage of one method of stratification over another in predicting cognitive performance during sleep loss. Thus, the discussion of the results will be on a general level with the Group stratification removed. The Fitness Levels were suggestive (although very weakly) that physical fitness may have a moderating effect under certain conditions.

Tests and Performance

The preliminary analyses included number attempted, number correct, and percent correct. The number attempted was chosen as the best indicator of performance across days. The measure of the difficulty of the different tests, however, was the percent correct. This data indicated that the Logical Reasoning test was the least difficult-- and least affected by sleep deprivation-- and the Encode/Decode test was the most difficult and most affected by sleep deprivation. This is consistent with previous sleep deprivation investigations in that the longer (time) tasks suffered the greatest performance decrements.

Days.

The effect of time (days) on the cognitive performance of the participants was impressive. Only 24 hours were required to produce significant decrements in performance on each of the three tests. Performance remained at this low level for the duration of the deprivation, indicating the powerful effect of missing one night's sleep on the ability

of the individual to perform cognitive operations under the pressure of time. The effect of 24 hours of deprivation is particularly significant because leaders, even in peace time, do not hesitate to miss a night's sleep during Army Training and Evaluation Tests, or field training exercises. There is a general trend for the leader to feel compelled to be "on top of the situation" at all times. This is generally interpreted as remaining awake. Thus, the leader-- the individual responsible for making the critical decisions-- is not performing at a very efficient cognitive level.

During this depressed level of cognitive performance, the participants demonstrated difficulty in land navigation, planning, and performing general combat related skills. If 24 to 72 hours of sleep deprivation has an effect this severe, what can be expected in continuous combat where the deprivation may extend for longer periods and involve more complex and critical decisions?

Recovery.

After 24 hours of recovery, performance levels had returned to pre-experimental levels (with the exception of the logical reasoning test). This indicates that after a short period (24-48 hours) of sleep deprivation, 24 hours should be enough recovery time for cognitive abilities to return to pre-deprivation levels. Longer deprivation periods may require longer recovery periods. The data from this investigation also indicate that different aspects of cognitive performance may have different recovery rates (as

indicated by the lack of recovery of the logical reasoning test).

Fatigue

Fatigue, for this investigation, was measured subjectively. That is, the participants reported their own level of "tiredness" and "sleepiness." This provided for a degree of inaccuracy due to "self-presentation" biases as well as bias due to individual differences in "self-awareness." Self-presentation is an effort by an individual to present himself to another (or others) in such a way as to create what he perceives as a favorable image for the particular situation. For example, if the participant in this investigation perceived the need to be seen as "macho," he may have altered (consciously or unconsciously) his self-report of fatigue to appear less tired, and, consequently, more macho.

Self-awareness would bias the results in an unconscious manner. For example, athletes normally are very self-aware of the operation of their bodies. They constantly monitor the performance of different muscle groups and their cardio-vascular system during athletic events. Because they train often, they become very adept at monitoring their system--much more so than the non-athlete. Thus, it is reasonalble to assume that athletes would be more accurate in reporting their level of fatigue than would non-athletes. If individuals were placed on a continuum ranging from a

very low level of physical conditioning to a high level of conditioning, one may find a high correlation with a continuum ranging from low self-awareness to high self-awareness.

The results of this investigation revealed a significant effect of Day indicating that as the experiment progressed, the participants reported more fatigue. This was expected. What was interesting was the actual effect of conditioning Levels. The Below Average physical condition Level reported feeling less fatigued (tired or sleepy) than the other, better conditioned, groups. Why? A possible explanation is the self-awareness hypothesis presented above. That is, the Below Average Level participants may not have been as "self-ware" as the other two groups, and, therefore, not have recognized their actual fatigue level, and therefore, reported being less tired.

If this lack of awareness was the result of an unconscious process, would the individual not eventually reach a level of fatigue of which he <u>was</u> aware? This would seem reasonable. The data, in fact, show that by Day 6, the Below Average Level had continued to increase their fatigue rating until they were at the same level as the other groups thus, lending support for the self-awareness hypothesis.

The recovery data also lend support to the self-awareness hypothesis. After 24 hours of recovery, the Above Average Level reported being more fatigued than the other groups, again indicating that they may have been more sensitive

(aware)to their fatigue level.

The implications of this hypothesis is that individuals who engage in regular physical training and have learned to be "self-aware," may recognize the onset of fatigue before a less physically fit or trainied individual. Although this is suggestive at this time, it does warrent further research.

Leadership

Previously cited research has indicated that individuals hold certain preconceived concepts about individual abilities such as leadership. One of these concepts is that leaders are in relatively good physcial condition. Based on this, it was expected that the individual's level of physical conditioning would moderate his leadership ability as perceived by the other participants. The data supported this. That is, the higher a participant scored on the fitness events, the higher his ultmate leadership rating. This hypothesis suggests that an individual's ability to lead in combat may be enhanced if he is perceived to be in relatively good physical condition.

Conclusions

The reader will recall that this was an exploratory study, and as such, operated under certain constraints. For example, a very small number of participants was used. This greatly reduced the power of the statistical tests used in

the analyses. Thus, even though the evidence from this investigation on the effect of physical conditioning on cognitive performance during sleep deprivation is not conclusive, it does suggest that there may be a relationship. If a larger, more controlled sample was used in a future investigation, it is very likely that a significant relationship would be found.

Another area for future consideration is the length (time-wise) of the tasks to be performed. This study supported previous findings that performance declines as task length (time) increases. Therefore, future tasks should be of longer duration than those used here. An attempt should be made to parallel the decision tasks made by commanders in <u>their</u> problem solving process.

This particular investigation also confounded mental and physical fatigue. It was intentionally done in this case as it increased construct validity. However, there is a need for future investigations to attempt to separate the effects of these two variables.

There are numerous other variables that impact on cognitive performance during sleep deprivation that need to be investigated. Webb contends that motivation is the primary factor in performance during sleep deprivation. Cognitive complexity is currently being investigated by several investigators (Streufert, 1976) and seems to affect information processing, particularly under varying levels of stress. Preliminary analyses of the quantitative score on

the Scholastic Aptitude Examination of the participants in this investigation and their cognitive performance revealed a high correlation.

In summary, sleep is vital to the individual soldier, staff officer, and leader at all levels. Any attempt at self-denial of sleep, regardless of how "macho" the individual is, will result in degraded performance. The leader, in particular, must understand the effects of sleep loss, its symptoms, and counter-measures. He must ensure that the unit, and himself, takes advantage of opportunities to sleep. Delaying the effects of sleep loss will require some non-traditional thinking and action on the part of the leader. We have been conditioned to believe that a leader must be everywhere,but, we must realize that in spite of the fact he is a "leader," he is still vulnerable to the weaknesses of the ordinary man. Thus, even the leader needs sleep.

Both the literature reviewed and the results of this investigation conclude that leaders, in particular, must structure their time to include at least some sleep each day. Additionally, a high level of physical fitness will aid the leaders and his subordinates in at least recognizing the onset of fatigue, if not delay it.

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APPENDIX A

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a true description of the pair of letters which follows it. Work as quickly and as accurately as possible.

Time limit: one minute

		Response
A does not come after B	AB	
B does not follow A	BA	
B comes after A	AB	
A does not come before B	AB	
A does not follow B	BA	
B is not followed by A	AB	
B does not follow A	AB	
A comes after B	BA	
A comes before B	AB	
A is not followed by B	AB	
B does not come after A	BA	
B comes before A	AB	
A does not follow B	AB	
A comes before B	BA	
B follows A	BA	
A does not come after B	BA	

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a true description of the pair of letters which follows it. Work as quickly and as accurately as possible.

Time limit: one minute

		Response
B does not come after A	AB	
A does not follow B	BA	
A comes after B	AB	
B does not come before A	AB	
B does not follow A	BA	
A is not followed by B	AB	
A does not follow B	AB	
B comes after A	BA	
B comes before A	AB	
B is not followed by A	AB	
A does not come after B	BA	
A comes before B	AB	
B does not follow A	AB	
B comes before A	BA	
A follows B	BA	
B does not come after A	BA	

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a <u>true</u> description of the pair of letters which follows it. Work as quickly and as accurately as possible.

Time limit: one minute

		Response
A comes after B	AB	
B follows A	BA	
B does not come after A	AB	
A comes before B	AB	
A follows B	BA	
B is followed by A	AB	
B follows A	AB	
A comes before B	BA	
A does not come before B	AB	
A is followed by B	AB	
B comes after A	BA	
B does not come before A	AB	
A follows B	AB	
A does not come before B	BA	
B does not follow A	AB	
A comes after B	BA	

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a true description of the pair of letters which follows it. Work as quickly and as accurately as possible.

Time limit: one minute

		Response
A follows B	AB	
B follows A	AB	
B comes before A	AB	
A does not follow B	AB	
B comes before A	BA	
A does not come before B	AB	
B is followed by A	AB	
B follows A	BA	
B comes after A	AB	
A comes after B	BA	
B comes after A	BA	
B does not come before A	BA	
A is followed by B	AB	
A follows B	BA	
A does not come after B	AB	
B does not come before A	AB	

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a true description of the pair of letters which follows it. Work as quickly and as accurately as possible.

Time limit: one minute

		Response
B comes before A	BA	
A does not come after B	BA	
B follows A	AB	
A does not come before B	BA	
A does not come after B	BA	
A is followed by B	AB	
A comes before B	BA	
B does not follow A	AB	
A comes after B	BA	
A does not follow B	BA	
B is not followed by A	BA	
A follows B	BA	
B does not come after A	AB	
B comes after A	BA	
B does not follow A	BA	
A does not come before B	AB	

TEST A

S.S. No. _____

Code No. _____

Instructions: For each sentence below place a check in the space provided if the sentence is a true description of the pair of letters which follows it. Work as quickly and as accurately as possible.

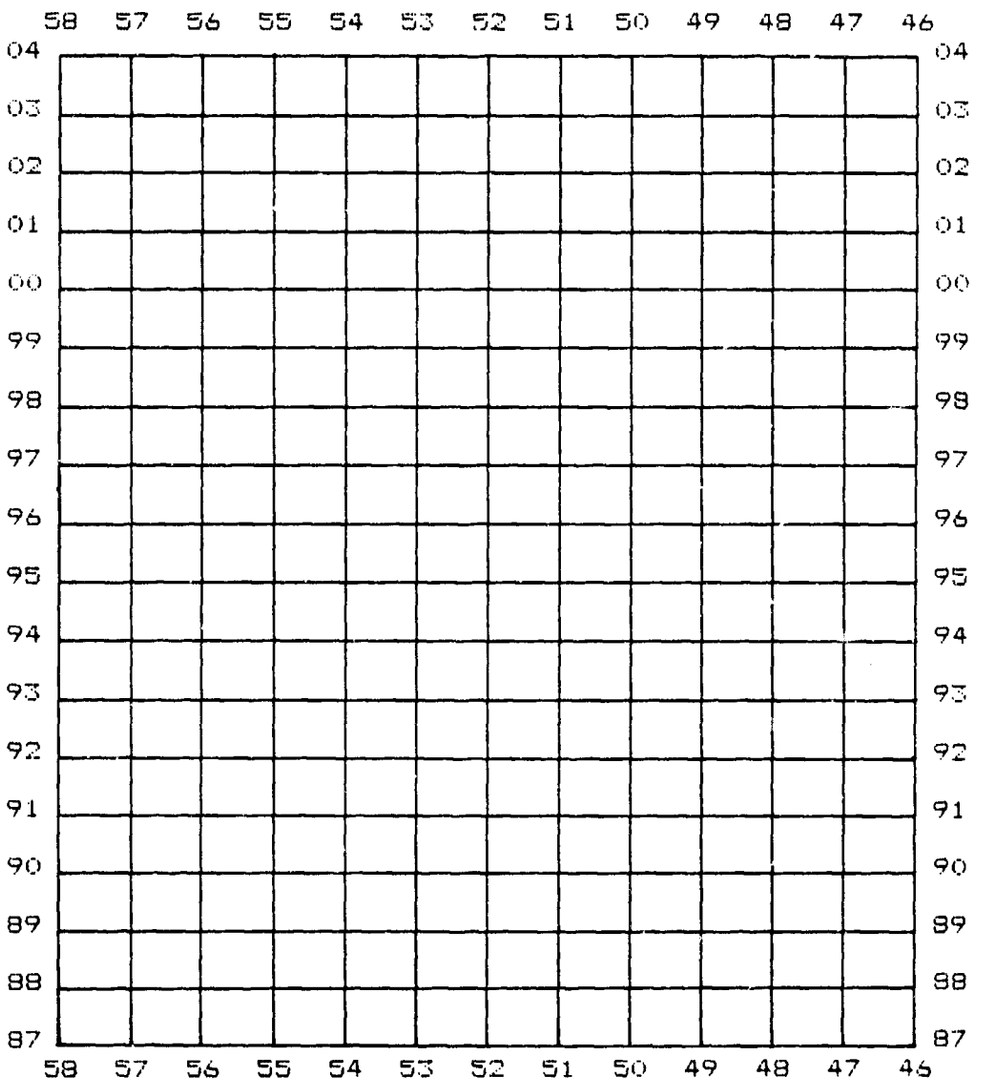
Time limit: one minute

		Response
A does not follow B	BA	
A does not come before B	AB	
B follows A	AB	
A does not come after B	AB	
A is followed by B	AB	
B does not come before A	BA	
B comes after A	AB	
B comes before A	BA	
A does not come after B	BA	
B is followed by A	AB	
B does not follow A	AB	
A does not come after B	BA	
B does not come before A	AB	
B does not come after A	AB	
A does not follow B	AB	
B comes after A	BA	

APPENDIX B

TEST B

MAP



NOTE: The actual map grid used by the participants had grids that were 1.5 cm square.

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1) 023479

(2) 923476

(3) 967525

(4) 034568

(5) 006554

(6) 933473

(7) 001507

(8) 886473

(9) 032537

(10) 923563

(11) 892507

(12) 886502

(13) 946469

(14) 871509

(15) 931472

(16) 024576

(17) 009576

(18) 899523

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1)	925485	(10)	911468
(2)	001467	(11)	013568
(3)	034482	(12)	875509
(4)	002547	(13)	892502
(5)	999557	(14)	883479
(6)	947578	(15)	876511
(7)	876567	(16)	032468
(8)	027576	(17)	913532
(9)	026478	(18)	979534

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1) 903561

(2) 969553

(3) 887556

(4) 882578

(5) 015479

(6) 994498

(7) 896527

(8) 878489

(9) 023483

(10) 025556

(11) 898567

(12) 927534

(13) 906537

(14) 872578

(15) 873576

(16) 992576

(17) 875493

(18) 889502

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1) 890576

(2) 954579

(3) 015556

(4) 882536

(5) 027485

(6) 923541

(7) 877565

(8) 005506

(9) 967577

(10) 011476

(11) 901545

(12) 945534

(13) 007535

(14) 932567

(15) 022476

(16) 021561

(17) 923577

(18) 883571

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1) 873476

(2) 897546

(3) 886472

(4) 897486

(5) 012576

(6) 887506

(7) 972495

(8) 997484

(9) 967523

(10) 906522

(11) 038579

(12) 931547

(13) 872547

(14) 037473

(15) 956524

(16) 979497

(17) 871499

(18) 023476

TEST B

S.S. No. _____

Code No. _____

Instructions: Plot each of the following grid coordinates on the map grid provided and label the point by using the number that is in parenthesis to the left of the coordinate. Work as quickly and as accurately as possible.

Time limit:

---

(1) 017549

(2) 873503

(3) 002486

(4) 923578

(5) 032471

(6) 899517

(7) 973579

(8) 025463

(9) 037485

(10) 962516

(11) 911517

(12) 872564

(13) 996467

(14) 933485

(15) 897577

(16) 027571

(17) 876562

(18) 014572

APPENDIX C

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	O	B	N	X	C	J	E	W	K	A	T	L	Q	Z	V	R	D	F	I	M	U	Y	H	S	P	G
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	H	G	V	C	Y	L	N	D	T	M	R	X	E	U	F	Z	W	I	J	O	S	Q	B	K	A	P
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	704187	WNDA
2.	655311	FRCU
3.	487269	MRJN
4.	634344	JUOK
5.	580156	DNVI
6.	523114	AXYW
7.	578148	FBGJ
8.	702367	ULVT
9.	549315	YLAR
10.	516156	QRNJ
11.	539330	BTAF
12.	515193	NBAY
13.	611262	AXNI
14.	689180	ZGEF
15.	693304	QADN

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	F	W	S	B	N	Q	I	R	H	G	M	J	U	O	Z	E	D	L	Y	V	T	A	P	C	X	K
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	B	N	L	C	D	P	T	I	G	Y	F	Z	S	M	K	J	Q	A	H	E	X	O	R	U	V	W
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	623259	EPDX
2.	674282	QDLB
3.	660328	NSMW
4.	665285	KEJI
5.	452246	ANER
6.	645217	DVNY
7.	511334	RGLE
8.	704315	PDAF
9.	709348	JNTK
10.	654319	WZED
11.	533213	NOVE
12.	567315	QJSB
13.	604367	SATV
14.	688321	RCYN
15.	665198	EGXQ

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	C	L	B	M	Z	A	N	K	O	J	P	I	Q	H	R	Y	G	S	X	W	F	T	V	E	U	D
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	J	L	A	K	N	B	M	P	C	O	S	D	R	Q	E	X	W	F	V	Y	G	T	U	H	Z	I
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	567137	BRAN
2.	623182	MDRS
3.	465248	WRIT
4.	642264	VITE
5.	539303	FAIR
6.	680326	ENTY
7.	708351	MGSH
8.	584365	UKGW
9.	456248	BJCW
10.	632297	TQZP
11.	669168	DPBY
12.	491130	WNNO
13.	567234	AFIA
14.	652265	KRVK
15.	698306	ZULD

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	H	D	X	Y	A	Z	M	B	I	J	F	N	L	O	P	W	C	E	S	R	K	G	T	Q	U	V
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	T	N	F	P	D	B	C	O	Z	A	U	J	I	M	L	Q	S	G	R	V	H	X	Y	K	E	W
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	709317	HSIY
2.	593361	RNMA
3.	660276	YRGB
4.	621275	AWHC
5.	589227	LOHJ
6.	456125	YOEC
7.	478262	MSPK
8.	467259	KAIY
9.	643308	MDAZ
10.	575216	HPKN
11.	678179	VKAU
12.	652278	WXQL
13.	475340	DJOI
14.	524233	ENJB
15.	505244	DNBA

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	Y	K	O	Z	G	F	R	H	N	C	W	I	U	P	X	E	B	L	D	V	S	A	Q	M	T	J
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	R	C	D	F	H	V	U	A	Z	Q	I	S	E	L	J	B	W	X	Y	P	K	N	M	O	T	G
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	473153	EJMK
2.	661286	XRLU
3.	663152	EPTX
4.	559321	AJDP
5.	466293	BTLD
6.	672225	JDAR
7.	690337	MCEL
8.	653278	NMIY
9.	645200	RDAN
10.	464339	ZLUW
11.	487164	VXNJ
12.	634193	QUIS
13.	578242	TROA
14.	509145	EQDN
15.	520204	PDWK

TEST C

S.S. No. _____

Code No. _____

Instructions: Using the East/North code strips which are printed below, and working from left to right, first encode the six digit grid coordinates and then decode the bigram which follows. Work across the page alternately encoding and decoding as quickly and as accurately as possible.

Time limit:

East	V	Q	A	K	J	G	W	D	I	Z	U	Y	C	F	T	B	H	R	S	X	M	O	E	L	P	N
	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
North	X	Y	Q	I	Z	E	P	B	R	O	A	K	H	U	V	D	M	W	F	S	N	J	C	T	L	G
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

	Encode	Decode
1.	453328	CROY
2.	500132	WENT
3.	567205	OPPS
4.	612248	UDTS
5.	643267	ZGBM
6.	680293	WNXO
7.	515311	GFTM
8.	462144	OJTN
9.	694176	ERZK
10.	513222	OZIA
11.	587256	XWDM
12.	476259	NPRL
13.	631261	DMNR
14	622295	ZWLJ
15.	528323	NHKQ

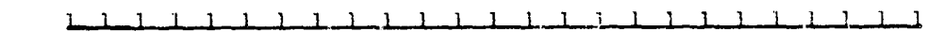
APPENDIX D

APPENDIX D

TIREDNESS SCALE

CODE NUMBER .....

Instructions: Circle that point on the scale below which best indicates HOW TIRED YOU ARE NOW.



Very Fresh — Very Tired

SLEEPINESS SCALE

Instructions: Circle the number of the statement which best describes YOUR PRESENT LEVEL OF SLEEPINESS.

1. Feeling active and vital; alert, wide awake.

2. Functioning at a high level, but not at peak; able to concentrate.

3. Relaxed, awake; not at full alertness; responsive.

4. A little foggy; not at peak; let down.

5. Fogginess; beginning to lose interest in remaining awake, slowed down.

6. Sleepiness; prefer to be lying down; fighting sleep; woozy.

7. Almost in a dream; will be asleep soon; lost struggle to remain awake.

APPENDIX E

APPENDIX E

PEER RATING

The purpose of this peer rating is to obtain your evaluation of the other cadets that participated in Operation Pheonix. You are to rate the other participants on their demonstrated potential for leadership ability. Your ratings will range form "1" (the highest potential) to "14" (the lowest potential). Use only the numbers 1-14. Place the appropriate number in the parenthesis next to the individuals' names. DO NOT RATE YOURSELF!.

LONDON ( )

DAVIS ( )

MOORE ( )

CALVERT ( )

YATES ( )

PATTON ( )

NELLIGAN ( )

DYER ( )

FISHER ( )

STEELE ( )

HOWARD ( )

SAWYERS ( )

SIMMONS ( )

SNOWDEN ( )

HAMIL ( )

BE SURE THAT YOU HAVE RATED EVERYONE AND USED EACH NUMBER ONLY ONCE.

APPENDIX F

APPENDIX F

STEP TEST

1. Equipment:

   a. A sturdy bench, 15 1/4 inches high.

   b. A Metronome set for 90 beats per minute.

   c. A stop watch.

2. Procedure:

The overall procedure, to include a safety briefing, was explained to the participants along with a demonstration of the stepping procedure. On the command of "start," the participants began to step up on to the bench with both feet and back to the floor, keeping time with the metronome. After exactly 5 minutes, the command of "stop" was given. Five seconds after the stop command, the pulse was taken (at the wrist) for exactly 15 seconds. The pulse count, thus obtained, was used as the "step pulse."

APPENDIX G

APPENDIX

SEQUENCE OF EVENTS

CODE NUMBER .....

DAY	TIME	EVENT
TUES	1515	Administer cognitive battery #1
WED	1515	Administer cognitive battery #2
THU	1515	Administer cognitive battery #3
FRI	1600	Administer cognitive battery #4 and TSQ #1
	1620	Orientation
	1630	Physical fitness evaluations
	1800	Company operations order
	1905	Warning order
	1945	TOC coordination
	2100	Patrol order
	2230	Rehearsal
	2300	Administer TSQ #2
	2310	Depart for training area
SAT	0015	Passage of FFU
	0200	Conduct ambush
	0300	Occupy patrol base
	0300	TSQ #3
	0330	Warning order
	0430	Patrol order
	0630	Conduct raid
	0700	TSQ #4
	0800	Partisan linkup
	0830	Chow
	0830	Weapons turn-in
	0900	Land navigation orientation
	0930	Day land navigation course
	1100	TSQ #5
	1200	Map reading diagnostic
	1300	Ranger diagnostic
	1400	Military skills diagnostic
	1500	TSQ #6
	1600	Cognitive battery #5
	1630	Company operations order
	1715	Warning order
	1900	TSQ #7

	1910	Patrol order
	2010	Rehearsal
	2100	Begin sleep phase
	2300	Sleep phase terminated/TSQ #8
SUN	2400	Stress phase begins
	0300	TSQ #9
	0700	TSQ #10
	1100	TSQ #11
	1200	Stress phase ends
	1400	Ranger board
	1500	TSQ #12
	1600	Cognitive battery #6
	1630	Problem terminates
MON	1600	Cognitive battery #7 and post-experimental questionnaire

APPENDIX H

APPENDIX H

POST-EXPERIMENTAL QUESTIONNAIRE

CODE NUMBER:____

1. How much sleep did you get on the Sunday following Operation Phoenix?

_____hours

2. a. Did you find it necessary to make any changes in your routine for the week following Operation Phoenix?(Circle "yes" or "no.")

YES NO

b. If "yes," specify (i.e.,skipped class, missed work, stayed home more, etc.)

3. When (date, time) did you feel completely recovered from Operation Phoenix?

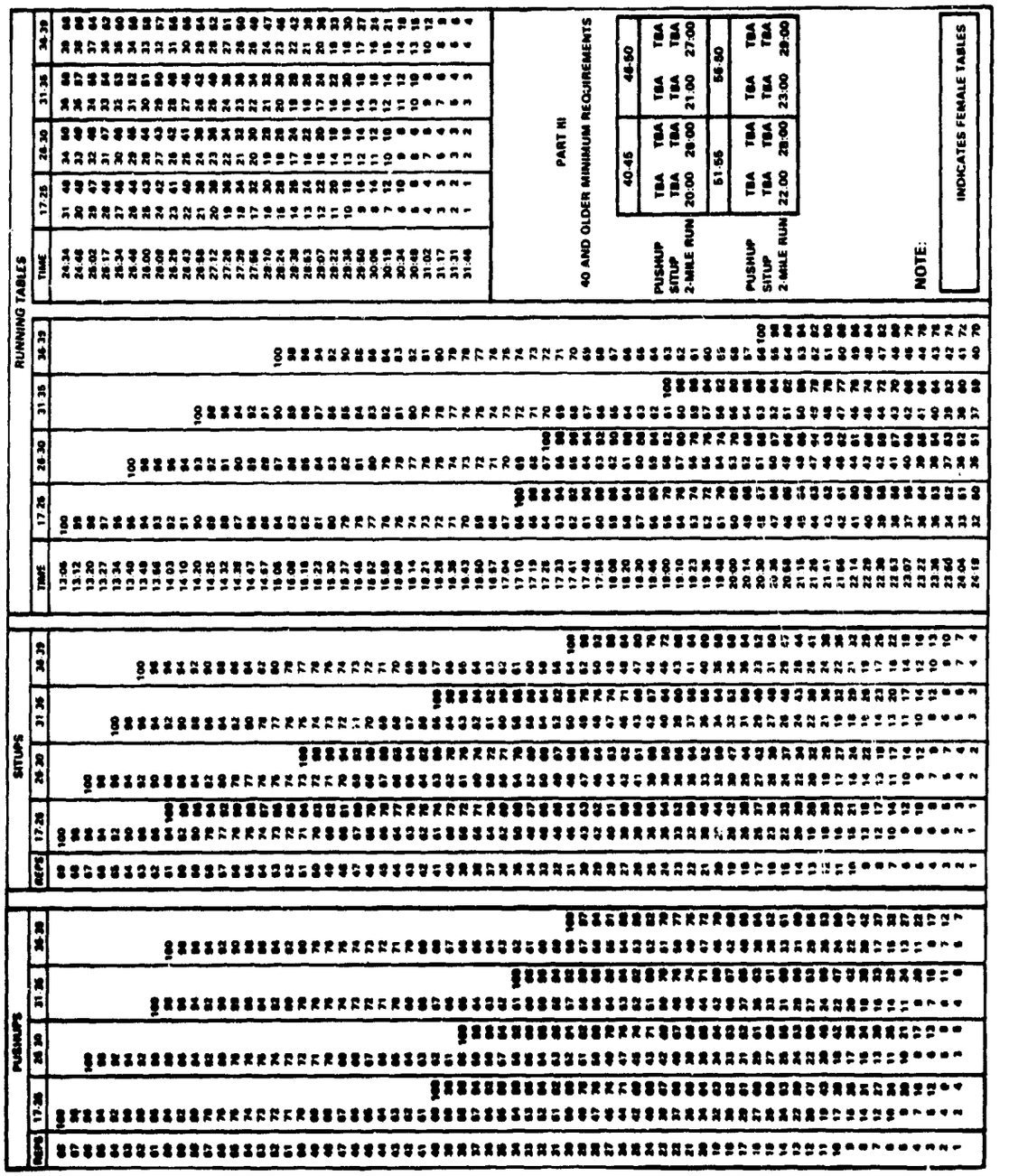
4. What was your "max" bench press the Monday before operation Phoenix?

5. What was your "max" bench press the Monday following Operation Phoenix?

*NOTE: Operation Phoenix was the code name of the Field Training Exercise (experiment).

APPENDIX I

Table 9
Physical Readiness Test Scoring Table



APPENDIX J

Table 10

Superfitness MANOVA Summary for Logical Reasoning Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	30.72	2	15.36	.43	.66
Error	425.22	12	35.44		
Within Subjects					
Day (D)	102.73	3	34.24	3.77	.02
D x F	84.53	6	14.09	1.55	.19
Error	326.74	36	9.08		

Table 11

Superfitness MANOVA Summary for Logical Reasoning Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	7.08	2	3.9	.33	.73
Error	142.64	12	11.89		
Within Subjects					
Day (D)	145.2	3	48.4	4.22	.01
D x F	74.81	6	12.47	1.09	.39
Error	412.49	36	11.46		

Table 12

Superfitness MANOVA Summary for Map Plotting Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	106.33	2	53.16	.6	.56
Error	1060.07	12	88.34		
Within Subjects					
Day (D)	51.38	3	17.13	3.33	.03
D x F	88.82	6	14.8	2.88	.02
Error	185.05	36	5.14		

Table 13

Superfitness MANOVA Summary for Map Plotting Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	46.75	2	23.37	.78	.48
Error	357.85	12	29.82		
Within Subjects					
Day (D)	209.73	3	69.91	7.71	0
D x F	112.95	6	18.83	2.08	.08
Error	326.31	36	9.06		

Table 14

Superfitness MANOVA Summary for Encode Decode Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	54	2	27	.14	.87
Error	2300.23	12	191.69		
Within Subjects					
Day (D)	215.87	3	71.96	8.79	0
D x F	127.03	6	21.17	2.59	.04
Error	294.6	36	8.18		

Table 15

Superfitness MANOVA Summary for Encode Decode Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	153.01	2	76.51	.83	.46
Error	1108.32	12	92.36		
Within Subjects					
Day (D)	197.73	3	65.91	4.72	.01
D x F	161.38	6	26.9	1.93	.1
Error	502.89	36	13.97		

Table 16

Superfitness MANOVA Summary for Tiredness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	77.44	2	38.72	.99	.4
Error	469.06	12	39.09		
Within Subjects					
Day (D)	718.73	3	239.58	15.86	0
D x F	257.99	6	43	2.85	.02
Error	543.77	36	15.11		

Table 17

Superfitness MANOVA Summary for Sleepiness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	.06	2	.03	.02	.98
Error	15.54	12	1.3		
Within Subjects					
Day (D)	30.72	3	10.24	11.16	0
D x F	13.49	6	2.25	2.45	.04
Error	33.04	36	.92		

APPENDIX K

SUPER1/DIF
17/11/82

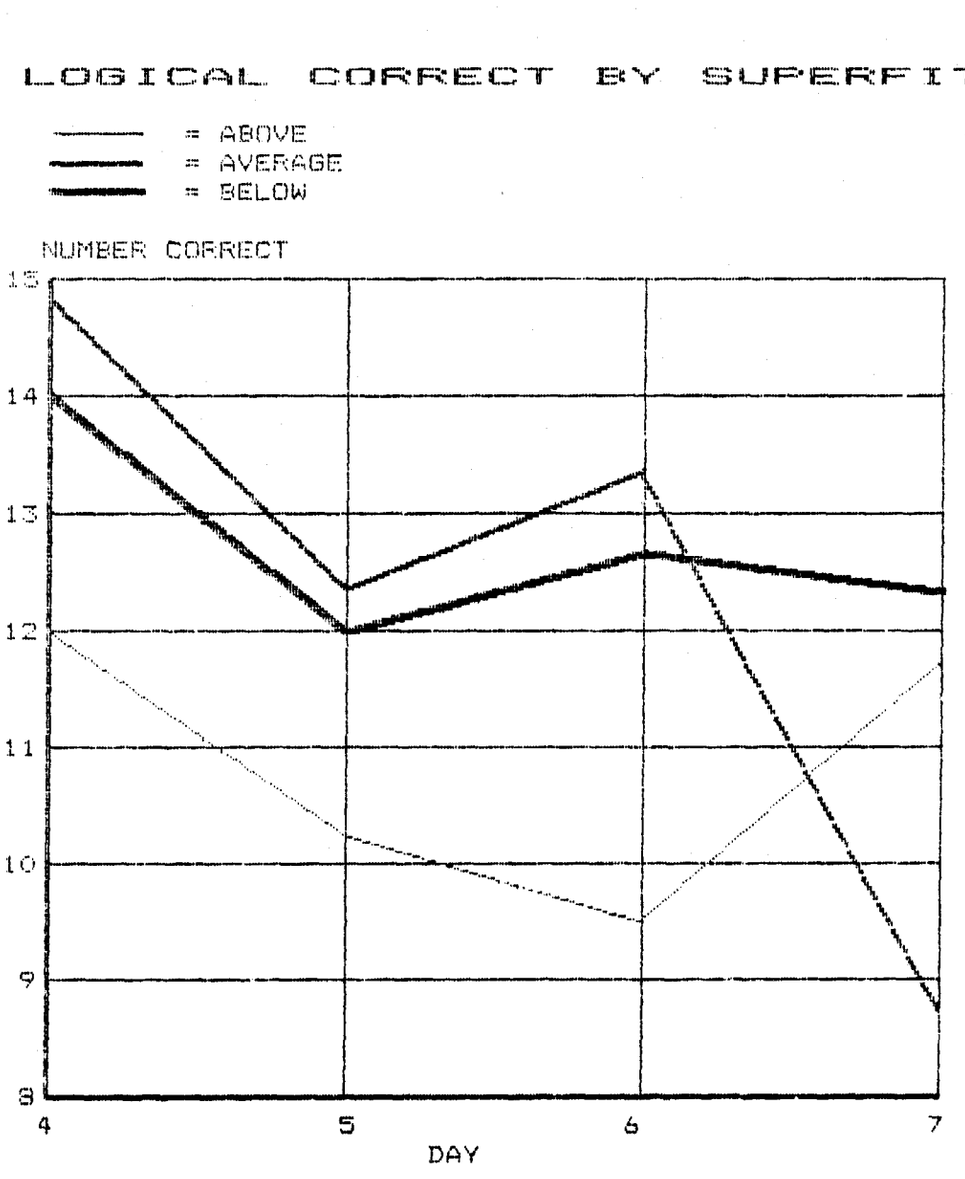


Figure 18

APPENDIX L

Table 18

APRT MANOVA Summary for Logical Reasoning
Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	13.08	2	6.54	.18	.84
Error	442.86	12	36.91		
Within Subjects					
Day (D)	102.73	3	34.24	3.26	.03
D x F	33.48	6	5.58	.53	.78
Error	377.79	36	10.49		

Table 19

APRT MANOVA Summary for Logical Reasoning
Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	5.35	2	2.68	.22	.8
Error	145.08	12	12.09		
Within Subjects					
Day (D)	145.2	3	48.4	3.79	.02
D x F	27.35	6	4.56	.36	.9
Error	459.95	36	12.78		

Table 20

APRT MANOVA Summary for Map Plotting
Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	77.53	2	38.77	.43	.66
Error	1088.87	12	90.74		
Within Subjects					
Day (D)	51.38	3	17.13	3.13	.04
D x F	76.56	6	12.76	2.33	.05
Error	197.31	36	5.48		

Table 21

APRT MANOVA Summary for Map Plotting
Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	13.5	2	6.75	.21	.82
Error	391.1	12	32.59		
Within Subjects					
Day (D)	209.73	3	69.91	6.4	0
D x F	46.04	6	7.67	.7	.65
Error	393.23	36	10.92		

Table 22

APRT MANOVA Summary for Encode Decode
Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	.05	2	.03	0	1
Error	2354.18	12	196.18		
Within Subjects					
Day (D)	215.87	3	71.96	8.18	0
D x F	105.05	6	17.51	1.99	.09
Error	316.58	36	8.79		

Table 23

APRT MANOVA Summary for Encode Decode Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	79.75	2	39.88	.41	.68
Error	1181.58	12	98.47		
Within Subjects					
Day (D)	197.73	3	65.91	4.18	.01
D x F	96.74	6	16.12	1.02	.43
Error	567.52	36	15.77		

Table 24

APRT MANOVA Summary for Tiredness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	101.44	2	50.72	1.37	.29
Error	445.06	12	37.09		
Within Subjects					
Day (D)	718.73	3	239.58	15	0
D x F	226.81	6	37.8	2.37	.05
Error	574.96	36	15.97		

Table 25

APRT MANOVA Summary for Sleepiness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	.13	2	.07	.05	.95
Error	15.47	12	1.29		
Within Subjects					
Day (D)	30.72	3	10.24	10.15	0
D x F	10.21	6	1.7	1.69	.15
Error	36.32	36	1.01		

APPENDIX M

SLEEP13/DIF
16/11/82

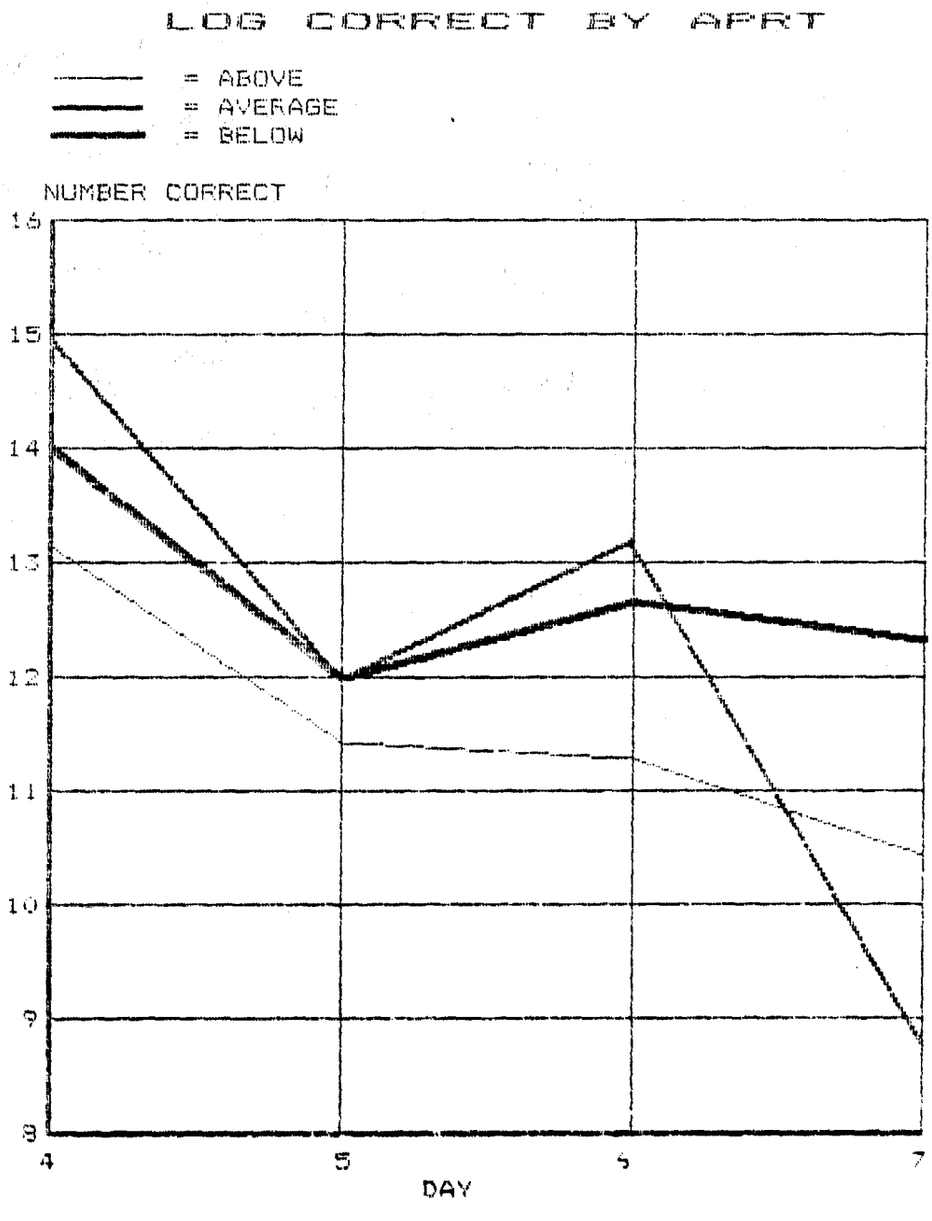


Figure 19

SLEEP14/DIF
16/11/82

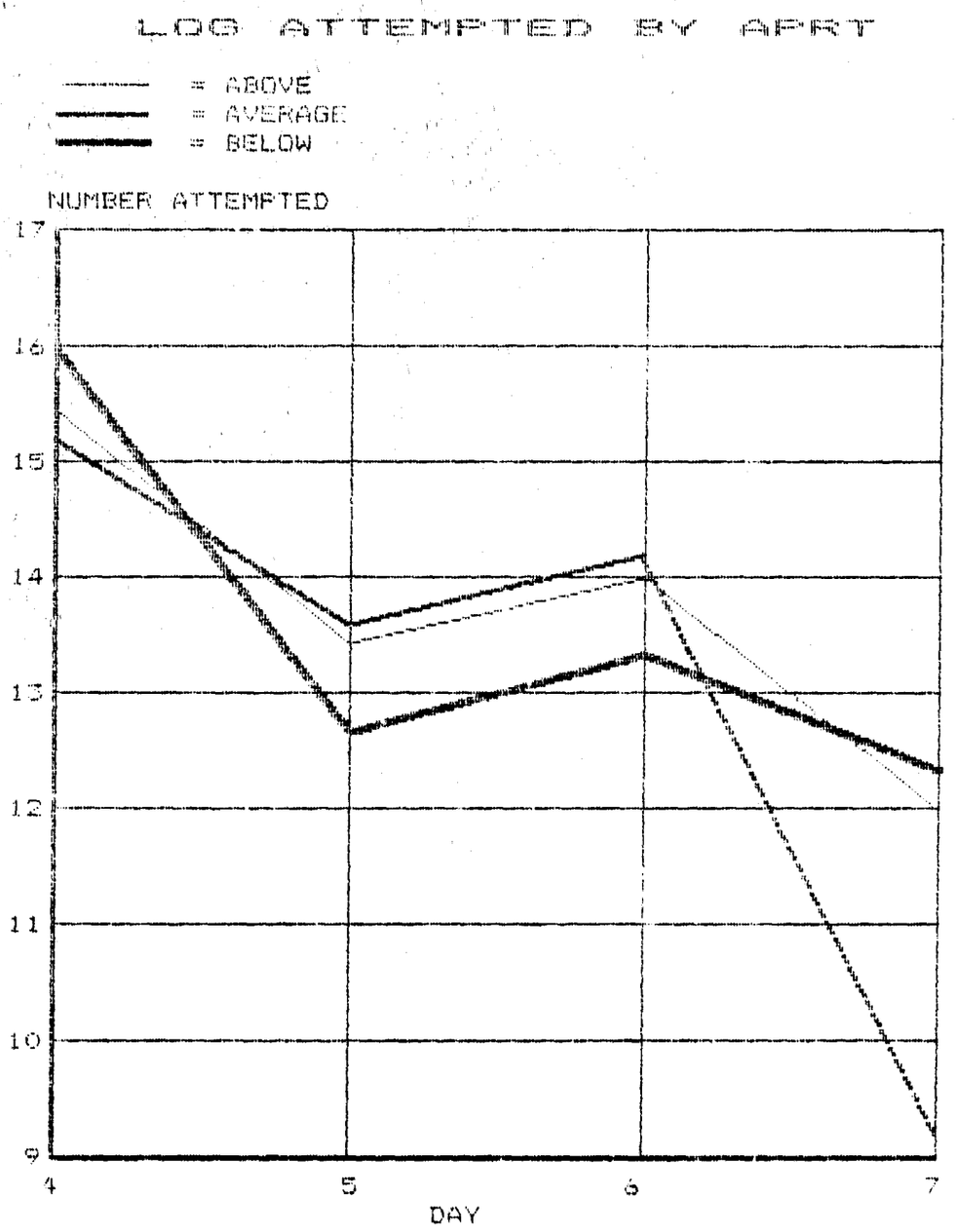


Figure 20

SLEEP16/DIF
16/11/82

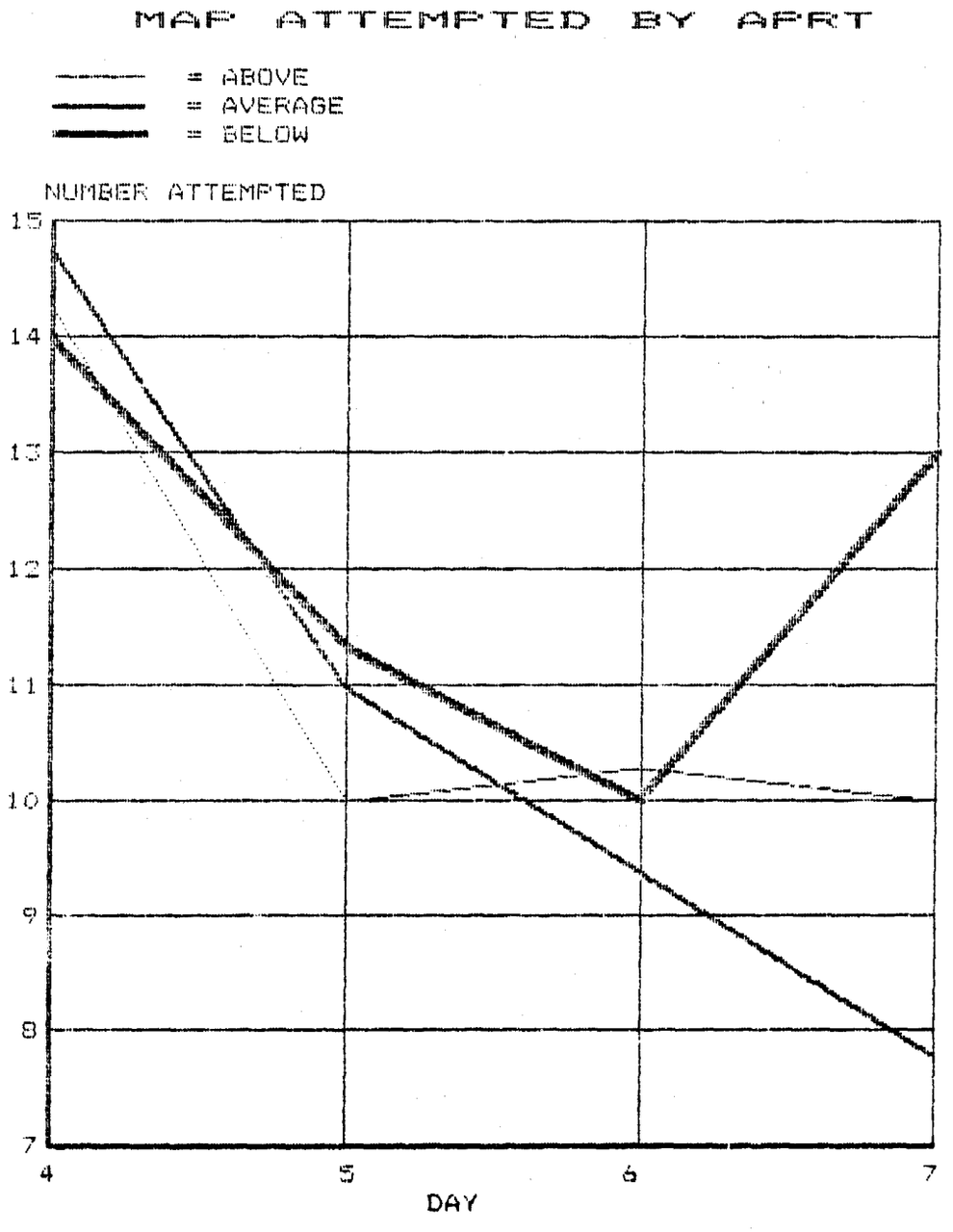


Figure 21

APPENDIX N

Table 26

Aerobic MANOVA Summary for Logical Reasoning
Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	64.2	2	32.1	.89	.43
Error	468.23	12	36.02		
Within Subjects					
Day (D)	112.39	3	37.46	4.49	0
D x F	32.88	6	5.48	.66	.69
Error	292.23	35	8.35		

Table 27

Aerobic MANOVA Summary for Logical Reasoning
Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	.49	2	.25	.01	.99
Error	220.78	13	16.98		
Within Subjects					
Day (D)	144.97	3	48.32	4.58	.01
D x F	47.27	6	7.88	.75	.62
Error	369.42	35	10.56		

Table 28

Aerobic MANOVA Summary for Map Plotting
Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	42.01	2	21	.23	.8
Error	1198.84	13	92.22		
Within Subjects					
Day (D)	50.34	3	16.78	3.65	.02
D x F	39.41	6	6.56	1.43	.23
Error	161.06	35	4.6		

Table 29

Aerobic MANOVA Summary for Map Plotting
Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	85.05	2	42.53	1.33	.3
Error	414.94	13	31.92		
Within Subjects					
Day (D)	203.29	3	67.76	7.24	0
D x F	22.84	6	3.81	.41	.87
Error	327.48	35	9.36		

Table 30

Aerobic MANOVA Summary for Encode Decode Number Correct

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	37.8	2	18.9	.11	.9
Error	2335.47	13	179.65		
Within Subjects					
Day (D)	215.56	3	71.85	7.88	0
D x F	83.92	6	13.98	1.54	.2
Error	318.99	35	9.11		

Table 31

Aerobic MANOVA Summary for Encode Decode Number Attempted

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	213.76	2	106.88	1.27	.31
Error	1094.17	13	84.17		
Within Subjects					
Day (D)	190.24	3	63.41	3.96	.02
D x F	64.01	6	10.67	.67	.68
Error	561.16	35	16.03		

Table 32

Aerobic MANOVA Summary for Tiredness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	51.51	2	25.75	.69	.52
Error	484.98	13	37.31		
Within Subjects					
Day (D)	718.12	3	239.37	13.71	0
D x F	201.24	6	33.54	1.92	.11
Error	611.15	35	17.46		

Table 33

Aerobic MANOVA Summary for Sleepiness Scale

Source	SS	df	MS	F	p
Between Subjects					
Fitness (F)	.81	2	.41	.36	.7
Error	14.77	13	1.14		
Within Subjects					
Day (D)	30.27	3	10.09	11.36	0
D x F	15.89	6	2.65	2.98	.02
Error	31.1	35	.89		

APPENDIX O

SLEEP19/DIF
16/11/82

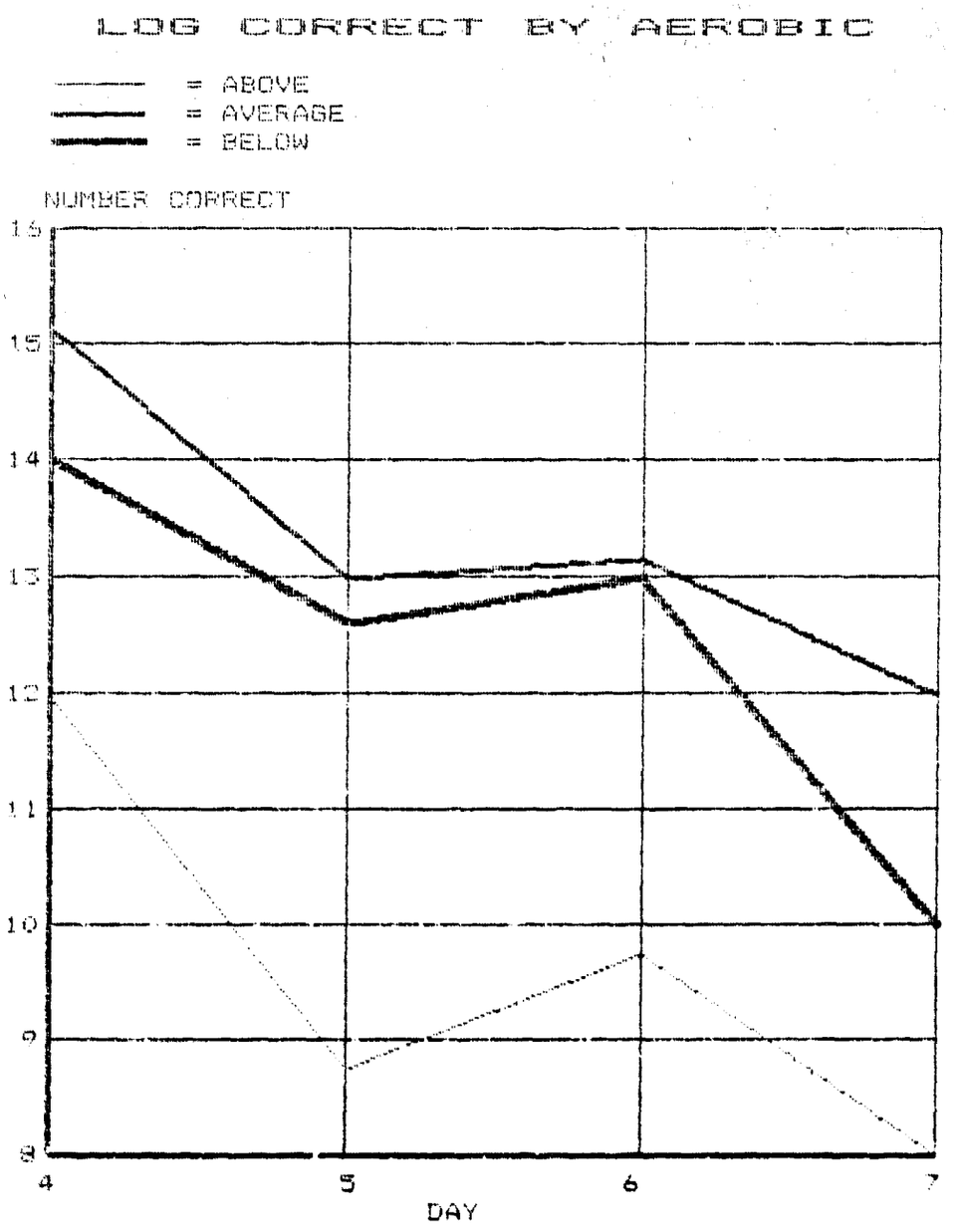


Figure 22

SLEEP20/DIF
16/11/82

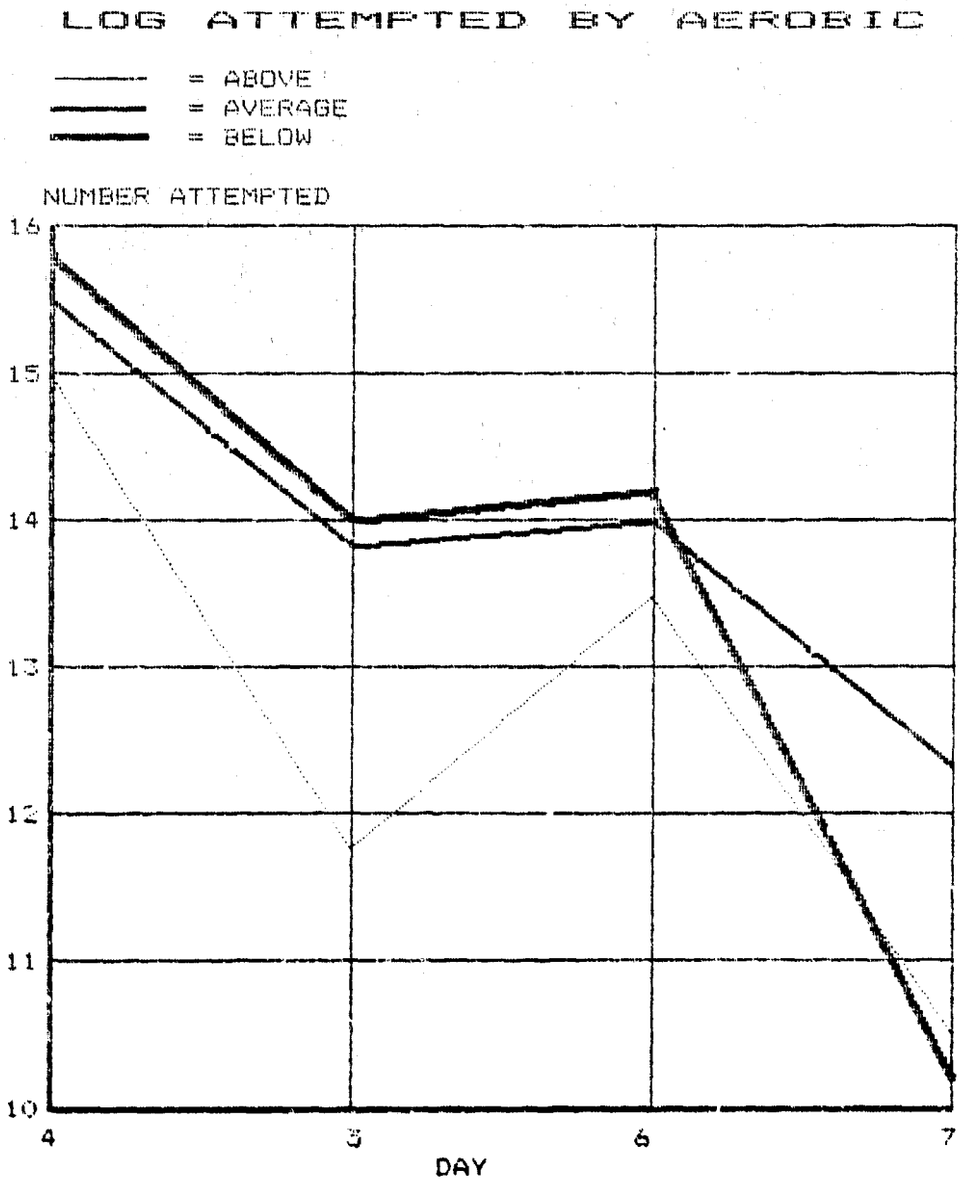


Figura 23

SLEEP21/DIF
16/11/82

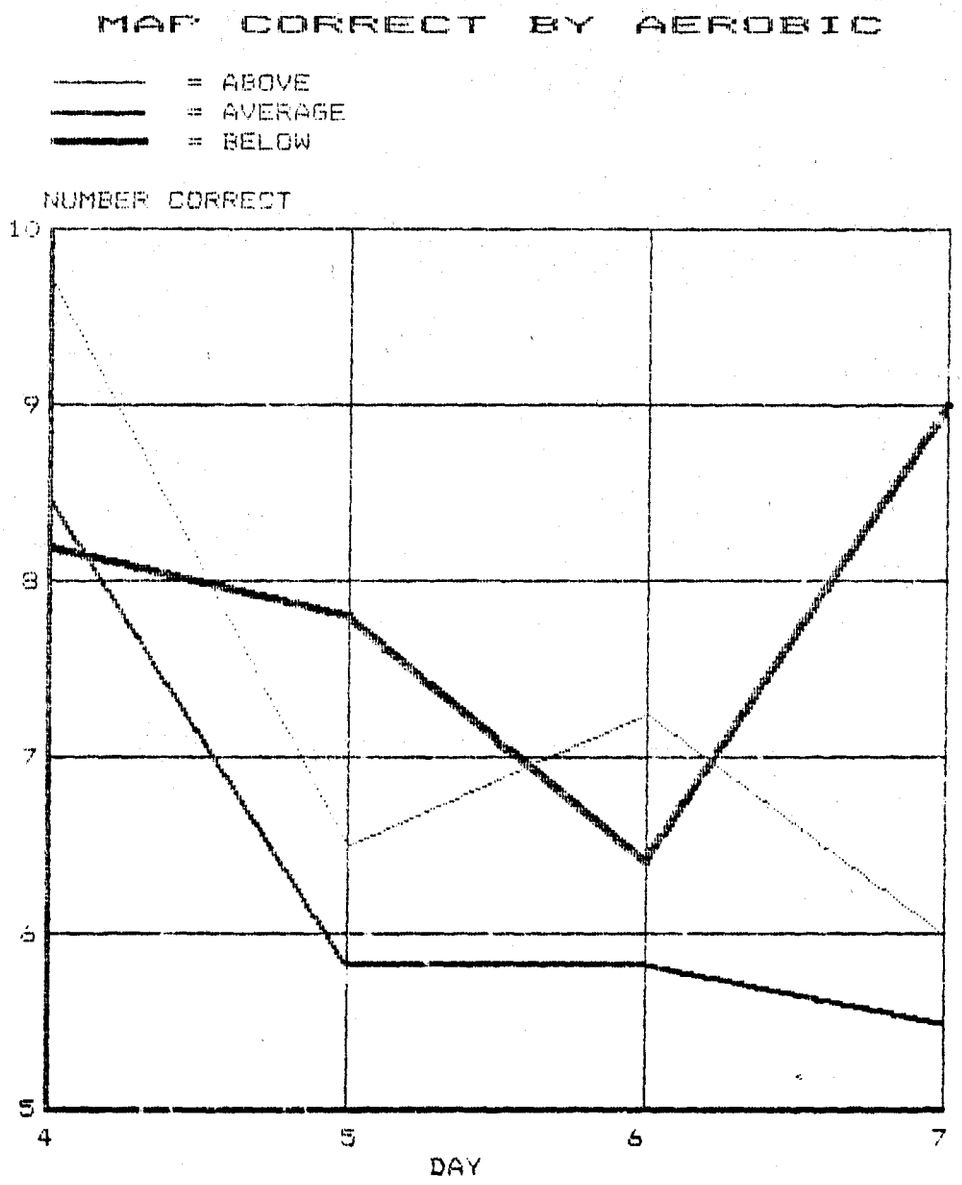


Figure 24

SLEEP22/DIF
16/11/82

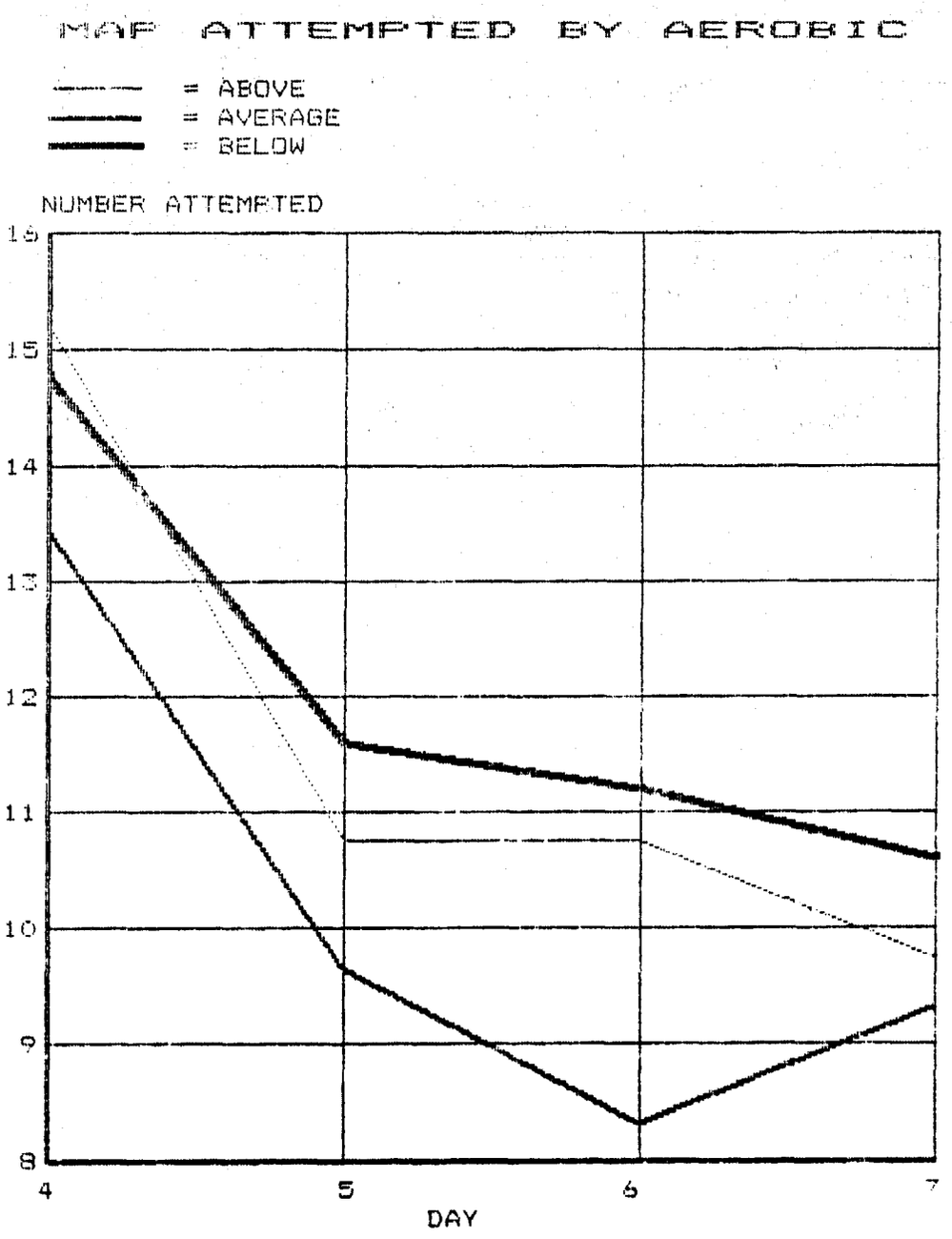


Figure 25

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